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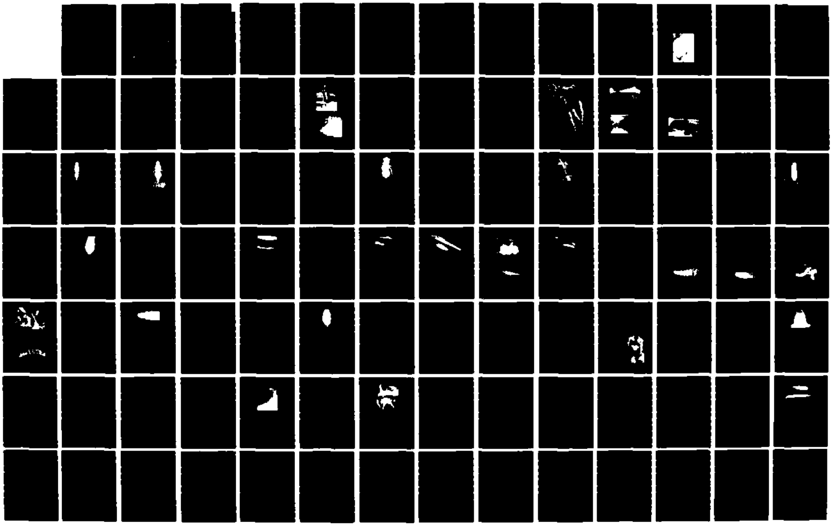

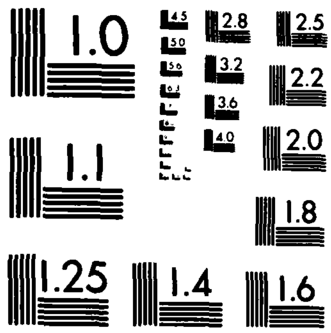

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AQUATIC PLANT CONTROL RESEARCH PROGRAM

MISCELLANEOUS PAPER A-84-2

US DEPARTMENT OF AGRICULTURE/ CORPS OF ENGINEERS COOPERATIVE AQUATIC PLANT CONTROL RESEARCH— ANNUAL REPORT FOR FY 1982

BIOLOGICAL AND CHEMICAL CONTROL TECHNOLOGIES

by

US Department of Agriculture, Southern Region
Gainesville and Fort Lauderdale, Florida

August 1984

Final Report

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Chapter 1

The purpose of the study reported in this chapter was to compile a list of insects associated with hydrilla in the United States. The fauna associated with hydrilla was surveyed by taking 267 collections of hydrilla from 58 Florida locations and an additional 22 collections of hydrilla from 17 out-of-state locations. Most of the Florida collections were made using a quantitative sampler to provide data on the density of insects and other fauna and to compare these densities with hydrilla standing crop. The quantitative results from six ecologically and geographically different sites are analyzed and discussed. Hydrilla biomass fluctuated greatly at any given site, and these fluctuations in biomass showed definite, predictable seasonal trends at only a few locations. Hydrilla biomass also varied greatly from location to location, peaking at 1013 g/m^2 (standing crop dry weight) at a clear, spring fed river, while never exceeding 100 g/m^2 at an oligotrophic lake.

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20. ABSTRACT (Continued).

Almost half of the 59,130 faunal specimens recorded during this survey were snails, with *Goniobasis floridense* being the most abundant (over 12,000 specimens). Densities of *G. floridense* exceeded 3200 snails/m^2 of hydrilla mat at one lotic site. Snail densities generally appeared to track biomass density directly. At least 25 species of snails were recorded from hydrilla, but most appeared to feed on the epiflora associated with hydrilla.

Over 17,000 insects were collected and these comprised almost 200 species. Analysis of a species accumulation curve for the insects found in the 267 Florida collections indicated that additional collections would continue to add additional insect species, but that only 35 more insect species would be added for every 100 additional Florida collections. Insect densities tended to peak around March, but this was highly variable. The peak insect density observed was 2691 insects/m^2 at Lake Lochloosa, but almost all of these insects were several species of midges (Diptera:Chironomidae). Midges were the most abundant insect group, comprising 57 percent of all insects collected. Some midge larvae in the genera *Endochironomus* and *Glyptotendipes* occasionally caused minor damage to hydrilla when they constructed burrows in hydrilla stems. Caddisflies (Trichoptera) comprised almost 25 percent of the insects collected. Of the 22 species of caddisflies, 5 species at least occasionally feed on hydrilla. Of these, *Leptocerus americanus* and *Nectopsyche tavara* were the most abundant. A half-dozen species of moth larvae feed on hydrilla leaves. Of these *Synclita obliteralis* and *Parapoynx diminutalis* were the most numerous and damaging. *Parapoynx diminutalis* is the only species of U.S. insect which shows a definite preference in the field for feeding on hydrilla.

Chapter 2

This chapter presents results of a biological control study of the Asian moth, *Parapoynx diminutalis* Snellen, for use against the problem aquatic plant, hydrilla. Biology and host range studies were conducted with *P. diminutalis*, a moth adventive in Panama and Florida. The eggs were deposited on the leaves and stems of hydrilla plants lying at the water surface. The larvae fed on the leaves and stems from tubular cases constructed from leaves. The larvae had spotted heads and feathery gills along their sides. The spotted heads distinguish them from native *Parapoynx* larvae, which are not spotted. A white cocoon was constructed inside a case attached to the stem from which the pupa obtained oxygen. Larval development was studied at different temperatures. Adults were found to mate the first night but not to begin ovipositing until the second night. The laboratory host range was studied in oviposition tests, larval no-choice development tests, and larval choice tests. There was little discrimination in small containers by ovipositing females and the larvae developed on at least 14 plant species. Young larvae, however, preferred hydrilla over most of the other test plants. Even though *P. diminutalis* was polyphagous in the laboratory, it has been found in the field almost entirely on hydrilla.

Because of its broad host specificity, it is unlikely that this insect agent would ever be used as a biocontrol agent for hydrilla. No further work is recommended on importation of this species; this is the final report upon which that decision was based.

Chapter 3

This chapter presents the results for FY 82 of an ongoing evaluation program of chemical formulations to determine their potential as aquatic weed control herbicides.

During FY 82, 28 chemicals were evaluated in the laboratory, greenhouse, outdoor aquaria, or in the field. Sixteen of these were experimental including nine controlled release (CR) formulations. Two clay-pellet formulations of Poly (GMA) 2,4-D were subjected to advanced evaluations in outdoor aquaria. One of these formulations controlled watermilfoil within 4 weeks, and control was maintained throughout the 20-week experiment. Flowing water bioassays were conducted in the laboratory for various CR formulations of dichlobenil and fluridone. The dichlobenil-alginate granules effectively inhibited hydrilla regrowth from tubers and rootstocks when concentrations of dichlobenil in the flowing water were maintained at 0.04 mg/ℓ or higher. Similar control of hydrilla regrowth was obtained in treatments with a CR formulation of fluridone to maintain 0.02 mg/ℓ of the chemical in the flowing water.

The experimental herbicide DPX 5648 continued to give promising results in field evaluations. Complete control of waterhyacinth was obtained with field treatment rates of 10 or 20 g a.i./ha. The persistence of the chemical in the aquatic environment is being investigated in a cooperative study with DuPont Company. Other experimental herbicides evaluated during the past year gave poor control of submersed aquatic plants in laboratory screenings. However, AC-925 showed promising results in greenhouse evaluations. Complete control of waterhyacinth and several other floating species was obtained 12 weeks after treatment with 0.11 kg/ha AC-925. The chemical AC-925 also gave adequate control of torpedograss at 0.28 kg/ha and alligatorweed at 0.56 kg/ha.

Hygrophila polysperma (Roxb.) Anderson, *Bacopa caroliniana* (Walt.) Robins., and *Cabomba caroliniana* var. *multiparita* were shown to be tolerant to most aquatic herbicides at levels currently being used for hydrilla control. The selectivity in herbicide responses appeared to be partly responsible for the recent weed problems with these species in various locations previously infested by hydrilla.

PREFACE

The work reported herein was performed under Agreement Nos. 12-14-7001-995 (Biological Control) and 12-14-7001-992 (Herbicide Evaluation) between the U.S. Department of Agriculture (USDA) and the U.S. Army Engineer Waterways Experiment Station (WES). Funds for the work were provided by the Office, Chief of Engineers (OCE), under Department of the Army Appropriation No. 96X3122, Construction General, 902740, through the Aquatic Plant Control Research Program (APCRP) at WES. Mr. Dwight Quarles was OCE Technical Monitor.

Chapter 1 of this report was prepared by Dr. Joseph K. Balciunas and Mr. Marc C. Minno, Aquatic Plant Management Laboratory, USDA, Fort Lauderdale, Fla.

Chapter 2 was prepared by Dr. Gary R. Buckingham, Biological Pest Control Research Unit, USDA, Gainesville, Fla., and Ms. Christine A. Bennett, University of Florida, Gainesville, Fla.

Chapter 3 was prepared by Drs. Thai K. Van and Kerry K. Steward, Aquatic Plant Management Laboratory, USDA, Fort Lauderdale, Fla.

The principal investigator at WES for the biological control studies was Mr. Edwin A. Theriot and for the herbicide evaluations was Dr. Howard E. Westerdahl. During preparation of this report, Mr. J. Lewis Decell was APCRP Manager. Dr. John Harrison was Chief, Environmental Laboratory, WES.

Commander and Director of WES during preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
cubic feet per second	0.02831685	cubic metres per second
miles (U.S. statute)	1.609347	kilometres

Chapter 1

A Quantitative Survey of the Insects and Other Macrofauna Associated With Hydrilla

by

Dr. Joseph K. Balciunas, Mr. Marc C. Minno

INTRODUCTION

Purpose and Scope of Present Study

The purpose of this study was to complete a list of insects associated with hydrilla (*Hydrilla verticillata* (Lf.) Royle) in the United States. The population dynamics of both the insects and their plant host were also investigated by means of sequential quantitative sampling at many Florida sites. These studies will aid in the foreign exploration for natural enemies of hydrilla and will provide data for assisting in evaluating the impact of aquatic plant management practices on the fauna associated with hydrilla.

Taxonomy

Description. Hydrilla is a perennial, submerged, rooted, vascular plant (Figure 1). It is placed in the family Hydrocharitaceae. Other members of this family commonly found in the United States include: *Egeria, Elodea,* and *Vallisneria.*

Hydrilla roots are long, slender, and simple, whitish or light brown in

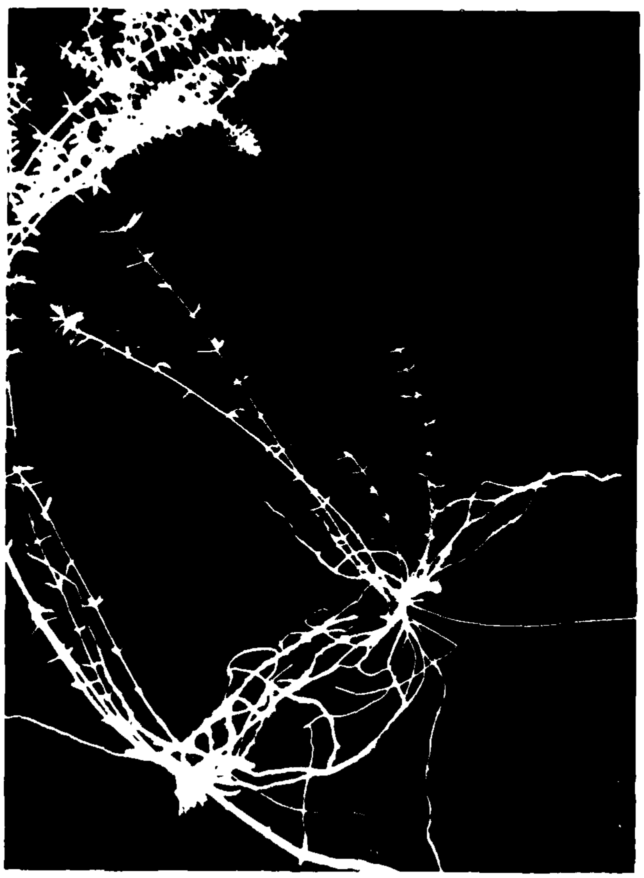

Figure 1. A typical hydrilla plant showing growth habit, roots, stolons, and tubers

appearance. They are usually buried in hydrosoil, but also form adventitiously at nodes. Stems are long, usually branching, growing from the hydrosoil and frequently forming dense, intertwined mats at the surface of the water. Detached portions of hydrilla plants remain viable and are a common mode for infestation of new areas. Below the hydrosoil, the stems are horizontal, creeping, and stoloniferous. Leaves are opposite, usually occurring in whorls and normally numbering three to five per node. Apical portions of the stem usually have the nodes tightly clustered and bearing up to eight leaves. The leaves are usually strongly serrated with the teeth visible to the naked eye and each leaf terminates in a small spine. The midvein is sometimes reddish in color and is usually armed with an irregular row of spines. *Squamulae intravaginales* (nodal scales) are small (ca. 0.5 mm long) paired structures at the base of the leaves; they are lanceolate, hyaline, and densely fringed with fingerlike, orange-brown structures which are usually unicellular, although sometimes bicellular. Two types of hibernacula are produced: a brown, bulblike type at the ends of roots and stolons; and a green, conical form in axils of branches. In the United States, the former are usually called tubers and the latter turions.

Flowers are imperfect (unisexual) solitary, enclosed in spathes. The female flower is white, translucent, with three sepals, broadly ovate, about 1.2-3.0 mm long; the three petals alternate with the sepals which are much narrower and slightly shorter; the three stigmas are minute; the ovary is at the base of the long (1.5-10+ cm) hypanthium. The male flower is solitary in leaf axils. Mature flowers abcise and rise to surface. Sepals and petals are similar in size and shape to those of female flowers. Each of three stamens bears a four-celled anther which produces copeous, minute, spherical pollen. Fruits and seeds have not yet been observed in the United States.

Pollination. Although the female hydrilla flower has been abundant at many U.S. locations, it was not until 1982, that the male flower was observed in the United States (Vandiver, Van, and Steward 1982). Hydrilla plants can be either dioecious, with only flowers of one sex being produced on a particular plant, or monecious, with flowers of both sexes being on the same plant. The flowers can only be pollinated in the air. The female flower reaches the water surface by elongation of the hypanthium (flower "stalk"). The petals and sepals of the female flower form an inverted bell with an air bubble when growing to the surface, and if after reaching the surface, the flower becomes submerged, the petal and sepals revert to this position, and enclose an air bubble thus preventing wetting of the stigmas and ensuring air-pollution. The male flower lacks a hypanthium, and reaches the surface by detaching from the plant and floating up as a ripe, air-filled bud. The perianth segments recurve towards the water surface and eventually the anthers dehisce explosively scattering pollen in a radius of about 10 cm around the flower. Where male hydrilla flowers are present, the water surface frequently becomes visibly white due to the floating pollen grains and discarded male flowers.

Taxonomic and identification difficulties. Hydrilla has been recognized as a separate species of plant since the early days of taxonomy. Linnaeus' son published a figure of it (described as *Serpicula verticillata*) in 1781. In 1839, Royle

was the first to correctly call it *Hydrilla verticillata*. However, throughout the nineteenth century, it was frequently placed in other aquatic genera such as *Udora, Elodea,* and *Vallisneria* and many additional species and "varieties" of *Hydrilla* were described in the literature. Cook and Luond (1982) provide an excellent, concise synonomy for *Hydrilla*. Most of the variation in the morphology of the leaves and stems, which caused the proliferation of *Hydrilla* species and variety names, is now known to be due to environmental factors. Thus, even though the chromosome number is not identical for all populations (i.e., polyploidy is evident), *Hydrilla* is currently considered a monotypic genus, containing only the species *verticillata* (Cook and Luond 1982).

Hydrilla is frequently misidentified when it first appears in a new area. When hydrilla first started becoming a problem in Florida in the early 1960s, it was called Florida elodea, reflecting the opinion that this was a new species or variety of *Elodea*. It has also frequently been confused with still another member of the family Hydrocharitaceae - *Egeria*. When flowering, these three genera are easily distinguished, but botanists will usually refrain from positively identifying sterile material. Persons with extensive field experience with hydrilla can usually reliably identify sterile plants even in the field. In the laboratory, the presence of small spines along the leaf margins, along with fingerlike processes on the nodal scales, can be used to confirm identifications of sterile hydrilla.

Distribution

The area of origin of *H. verticillata* is far from clear. Cook and Luond (1982, p 490), along with many other botanists, feel that "... its centre of origin lies in the warmer regions of Asia." However, hydrilla has been in central Africa for a long time (it was collected by Speke during his 1860-1863 expedition to find the sources of the Nile) and some botanists believe that it originated there (Tarver et al. 1978). Mahler (1979, p 5) is even more precise, stating "...with a center of distribution or origin in southeastern Uganda and northwestern Tanzania." It has also been recorded from Australia since the early portion of the nineteenth century, and some authorities believe hydrilla's center of origin to be in Australia.

Regardless of the area of origin of hydrilla, it is now widely dispersed with Antartica and South America now being the only continents from which it has not yet been recorded. It is very common on the Indian subcontinent, many of the Middle East countries, South East Asia, and northern and eastern Australia. In the southern hemisphere it is found as far south as North Island of New Zealand at a latitude of approximately 40°. In the northern hemisphere it is found as far north as Ireland, England, Poland, and Lithuania. The Lithuanian sites, at about 55° latitude, are the furthest from the equator that hydrilla is known to occur. Since virtually all of the continental United States lies below a latitude of 48°, hydrilla is climatically suited for growth in almost any of the 48 continguous states as well as Hawaii. Even Alaska cannot be considered entirely safe from invasion by hydrilla, since places such as Juneau and Ketchikan are at approximately the same latitude as the hydrilla infestations in Lithuania.

Hartog (1973, p 9) states, "The records from Panama are the first from the Americas," but unfortunately does not provide the date. Hydrilla's first U.S.

appearance was in Florida during the late 1950s or early 1960s. The earliest herbarium specimen seen by this author was collected in October 1962 at Big Lake Conway in Orlando, Fla., and is currently in the University of Florida Herbarium.

The spread of this plant throughout the United States during the last 20 to 25 years has been explosive. It is currently present in at least nine additional states (along with the District of Columbia): Alabama, California, Delaware, Georgia, Louisiana, Maryland, North Carolina, South Carolina, and Texas (Haller 1982).

Ecology

Hydrilla has very wide ecological amplitude, growing in a wide variety of aquatic habitats. It is usually found in shallow waters, 1/2 m or greater in depth. In very clear waters it can grow at depths exceeding 10 m. It tolerates moderate salinity — up to 33 percent of seawater (Mahler 1979). While it flourishes best in calcareous waters, water quality rarely seems to be limiting since it is found in both acidic and alkaline waters. It also grows well in both oligotrophic and eutrophic waters, and even tolerates high levels of raw sewage (Cook and Luond 1982). Sediments with high organic content provide the best growth, although hydrilla is also found growing in sandy and rocky substrates.

While hydrilla does not grow well in deeply shaded areas, it is adapted to grow under very low light conditions (Bowes et al. 1977) and this may account for its rapid growth and quick dominance over native vegetation.

Hydrilla is usually a gregarious plant and frequently forms dense, intertwined mats at the surface. Approximately 20 percent of the plant's biomass is concentrated in the upper 10 cm of such a mat (Haller and Sutton 1975). The plants grow and spread quickly with small fragments of the plant, containing but a single node, quickly developing adventitious roots and eventually producing an entire plant. Hydrilla fragments on recreational boat trailers appear to have been the mode of infestation of many new aquatic systems in Florida.

Economic Importance

Hydrilla has spread rapidly since its introduction into the United States less than 25 years ago. Burkhalter (1977) states that by 1965, 10,000 acres* were infested by hydrilla in Florida. This had increased to 50,000 acres by 1970, and to 500,000 acres by 1977. Approximately 200,000 acres out of these half-million acres were "topped-out" hydrilla.

Severe infestations impede water flow for irrigation and flood control, and restrict navigation and recreation. Drownings have occurred when swimmers became intangled in hydrilla. Properties adjoining infested areas have their values depressed. Guerra (1977) reports that the economic losses due to the presence of hydrilla in a single, medium-sized Texas lake (Lake Conroe) exceeded $30 million.

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* A table of factors for converting U.S. customary units of measurement to metric (SI) is presented on page 4.

The most visible of the costs entailed by the presence of hydrilla are the costs associated in attempting control. In excess of $8 million is spent annually, just in the state of Florida, on hydrilla control (Mahler 1979). With costs for chemical and mechanical control usually exceeding $200 per acre, and with several treatments usually required during the growing season, only high priority waters can be effectively managed.

Control Measures

Chemical. Managers of aquatic systems infested by hydrilla usually need effective, quick-acting results. For this they usually rely on herbicides. A great variety of chemicals, including concentrated solutions of sulfuric acid (Phillippy 1967), ammonia (Ramachandran 1960), and hydrogen peroxide (Quimby 1981), have been tried. Pieterse (1981) provides a thorough review of the extensive literature on controlling hydrilla with chemicals. Currently, the most commonly used herbicides for hydrilla control are diquat, diuron, and endothall. These are frequently combined with copper formulations to increase their efficacy and various copper complexes are occasionally used by themselves for hydrilla control.

The drawbacks to the use of herbicides are well known. Serious environmental consequences may result from placing poisons directly in aquatic systems. Not only may nontarget organisms, such as fish and invertebrates, be adversely affected, but also the potability of the water and its use for bathing and swimming by humans must usually be temporarily impaired. The dead, decaying plant material may also adversely affect water quality. Although the careful use of approved herbicides can overcome or at least ameliorate most of these problems, many countries (and a few states in the United States) severely restrict or prohibit the use of herbicides in aquatic systems.

Another factor limiting the use of herbicides is their cost. At $200 or more per acre per treatment, only high-use, high-priority waters can usually be treated.

Mechanical. In most developing countries, hydrilla (along with other nuisance aquatics such as waterhyacinth) is simply manually removed from the water. In more developed countries with their high labor costs, specially designed machines for harvesting submersed vegetation are sometimes employed.

Mechanical harvesting overcomes many of the environmental problems encountered when using herbicides. When the use of herbicides is restricted for legal or environmental reasons, mechanical harvesting is frequently the method of choice for achieving temporary control in small lakes or portions (e.g. fishing trails) of larger lakes. Unfortunately, the cost of mechanical control of hydrilla is usually as expensive and frequently more expensive than using herbicides with the actual cost being highly dependent on the distance the harvested hydrilla must be transported for disposal. McGehee (1979) reports costs of $1122 per hectare ($454/acre) when the hydrilla cuttings were placed back into a different portion of Orange Lake in north-central Florida. While the area used for disposal at Orange Lake was virtually 100 percent infested with hydrilla, hydrilla

fragments might root and form new plants, thus compounding the problem in aquatic systems with sparser or patchier hydrilla distributions.

Biological. Both chemical and mechanical measures for controlling hydrilla are costly and usually require multiple treatments during the growing season. The use of living organisms that consume or otherwise stress hydrilla has received increased attention. Currently, any such organism would be labeled as a "biological control agent."

Insects—Initially, the term "biological control" was more restrictive, describing the process of establishing introduced, foreign organisms to control an imported pest. The term "classical biological control" is now used to describe this traditional approach of reassociating a foreign pest with its natural enemies (usually insects) from its native range. An ideal biological control agent is highly specific — damaging only the target pest (and possibly a very limited number of other hosts) — and, once established, maintains population levels high enough to control the target pest.

During the past 100 years, this classical approach to biological control has been very successful in controlling a wide variety of weeds and insect pests. Classical biological control programs have also been successful in controlling several aquatic weeds. Alligatorweed, *Alternanthera philoxeroides*, has successfully been controlled in the United States by the beetle *Agasicles hygrophila* and two other insect species, all imported from Argentina. It also appears that waterhyacinth, *Eichhornia crassipes*, is being controlled by two Argentina weevils, *Neochetina* sp., in Louisiana and several other U.S. locations and that the recently released Argentine moth, *Sameodes albiguttalis*, is impacting waterhyacinth at some of its early release sites in Florida. In Australia, along with successes in controlling the above-mentioned aquatic nuisances, the control of *Salvinia molesta* by the South American weevil, *Cyrotobagous singularis*, has been reported at several locations (Room et al. 1981).

Unfortunately, no foreign insects to control hydrilla are presently available in the United States. Currently, the only foreign insect damaging hydrilla in the United States is the Asian moth, *Parapoynx diminutalis*. A native of tropical Asia, this moth was first discovered in Florida in the mid-1970s (Del Fosse, Perkins, and Steward 1976). It was probably an accidental introduction included in a shipment of aquarium plants.

The unavailability of insects for controlling hydrilla appears to be mainly due to the limited nature of the searches and testing in foreign countries of the natural enemies of hydrilla. Appendix A presents a chronology of the efforts in foreign countries to locate an acceptable insect species for use in controlling hydrilla in the United States. These searches began in the early 1970s with a U.S. Department of Agriculture (USDA) sponsored project conducted by CIBC scientists in Pakistan and a University of Florida sponsored project in Malaysia. During the mid-1970s, several U.S. scientists made short trips to Southeast Asia and Africa searching for hydrilla insects. The Pakistan project was the longest and most thorough and resulted in the most insects (10 species) found to damage hydrilla. Of these, the tuber-feeding *Bagous* weevil and the leaf-mining ephydrid

fly, *Hydrellia* sp., were found to be highly specific (but, unfortunately, not completely specific) to hydrilla.

In 1980, tests of a Panamanian moth species damaging hydrilla were conducted in Panama and this *Parapoynx* species was found to be fairly specific to hydrilla (Balciunas and Center 1981). Subsequently, permission to bring this moth into Gainesville quarantine facilities was obtained, but three subsequent collecting trips have failed to find this tested species, which was common in 1980.

In 1981 and 1982, Balciunas completed two trips, lasting a total of 10 months, to Kenya, India, Southeast Asia, and northern Australia in search of hydrilla insects. The emphasis of these early surveys was on locating the most appropriate areas which could serve as bases for future intensive studies. Many additional hydrilla damaging insect species (especially weevils and moths) have already been collected (Balciunas 1983).

The main drawback to establishing a classical biological control program of hydrilla is the high cost of the exploration and testing to find a proper insect species, and the long periods of time necessary to locate, test, release, and establish the species as a biological control agent. For these reasons, the level of interest (and funding) for locating an insect to control hydrilla has been low. The successful programs to find insects to control alligatorweed and waterhyacinth entailed the establishment of a laboratory in Argentina continuously staffed for more than 10 years by two scientists. Even with this intensive effort, it took more than 10 years from the time the first insect for controlling waterhyacinth was discovered in Argentina, until it was first released into the United States.

Fish—While no insects for controlling hydrilla are yet available, the use of fish as biological controls for hydrilla has received a great deal of attention. This concentration of effort has been primarily due to the ready availability of the grass carp (also called the white amur), *Ctenopharyngodon idella* Val. This large, herbivorous fish consumes enormous amounts of aquatic vegetation. While it will feed on almost any vegetation, including terrestial vegetation, that comes in contact with water, hydrilla is a preferred food. Grass carp are apparently effective in keeping small, enclosed aquatic systems free of hydrilla. The fish are usually considered to be unable to breed successfully in U.S. waters, although this is a hotly contested point at present.

Sutton (1977) reports that grass carp are banned in Canada and in 26 states of the United States. Apparently, this is due to fears of the possible impact of this large, imported fish on native fisheries. There has also been some concern that phytoplankton "blooms" will occur once the grass carp have consumed the macrophytes (Ewell and Fontaine 1982). Osborne and Sassic (1979) indicate that this has not occurred at the release sites they studied.

In order to overcome objections to the possible reproduction in the field by grass carp, there has been a recent, large amount of research into the hybrid grass carp, the sterile offspring of crossing a female grass carp and a male bighead carp, *Hypophthalmichthys nobilis* Rich. However, it appears that the hybrid is not nearly as effective as the grass carp. Osborne (1982), in his studies of effects of releases of the hybrid carp in eight Florida lakes, concluded that it was ineffective

in controlling hydrilla due to high mortality and extremely low feeding rate.

Tilapia zillii (Gervails) also consumes hydrilla (Legner 1979), but this fish is much smaller and does not damage hydrilla nearly as much as the grass carp.

***Other organisms*—**The snail, *Marisa cornuarietis*, consumes hydrilla and has been considered for use as a biological control agent. However, large numbers are necessary to achieve control, and *Marisa* is not completely specific, feeding on, among other things, young rice plants (Blackburn et al. 1971).

Manatee, *Trichechus manatus* L., consumes enormous amounts of aquatic vegetation, including hydrilla (Campell and Irvine 1977). However, this is an endangered species and any direct contact with the animal is illegal, making it impractical for use in management programs.

Several pathogens have been found on hydrilla, of which *Fusarium roseum* 'Colmorum' has shown the most virulency (Charudattan et al. 1980). However, this virulence is difficult to demonstrate in larger containers (Charudattan 1983).

METHODS AND MATERIALS

Collection and Identification

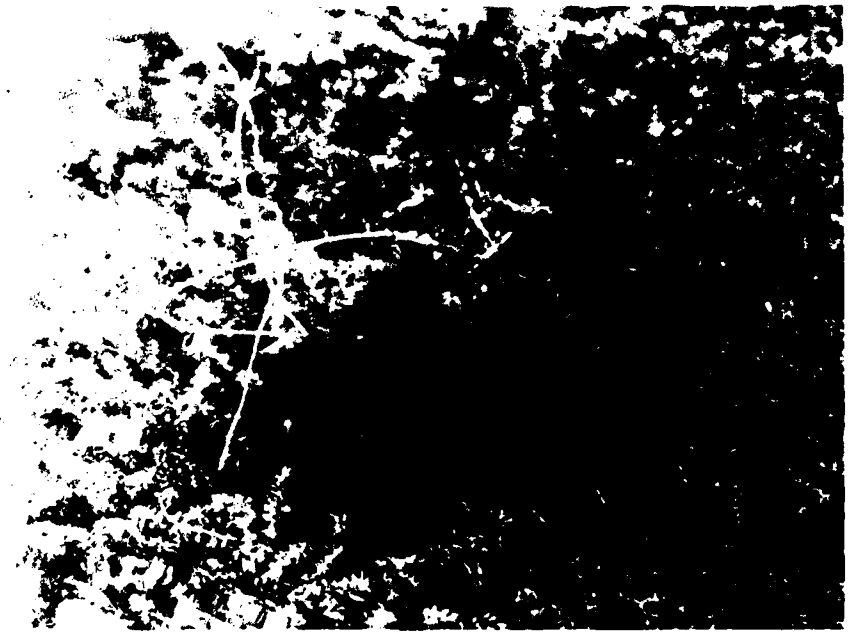
From July 1978 through July 1980, a sample of hydrilla, approximately 1 to 4 kg wet weight, was obtained at each collecting area with a rake or by hand from a dense portion of the mat, usually reached from a boat or an airboat. At sparsely infested areas, movement from one clump of hydrilla to another was necessary to obtain sufficient plant material.

Most of the Florida collections were made with a specially constructed sampler which removed a 0.125-m^2 portion of mat and associated fauna down to a depth of 4 m (Figure 2). The sampler was basically an aluminum box, open on both ends, with sharpened stainless steel blades on the bottom edges and a mesh bag over the top. A trap door with a screen bottom was closed by means of ropes once the sampler reached the bottom. When the sampler was used, five quantitative samples were usually taken in order to estimate the variability of both insect populations and hydrilla biomass.

Each hydrilla sample was placed in a plastic bag which had been marked with an identifying collection number. Initially the plant samples were immediately searched in the field for insects. From the end of 1978 onwards, all samples were searched in the laboratory in order to allow more time for field sampling and because microscopic examination produced greater numbers and variety of insects.

The following environmental data were recorded in the field notebook, under the corresponding collection number: water depth, mat depth (if below the surface), water temperature, salinity, conductivity, and water transparency. The depth of the water and mat were measured with a lead-line marked in 0.1-m intervals. Water temperature, salinity, and conductivity were measured with a Yellow Springs Instrument Company, Model 33, portable water quality meter.

a. Quantitative sampler used in this study for collecting *hydrilla* and associated invertebrates



b. Hydrilla mat showing a 0.125-m^2 section removed by the quantitative sampler

Figure 2. Sampling techniques

Water transparency was measured using a 20-cm Secchi disk attached to a line marked in 0.1-m intervals. Secchi disk transparency readings were difficult to obtain and of limited value since many sites were too shallow for disappearance of the disk.

Bagged samples of hydrilla were placed on ice as soon as possible; then they were frozen at the laboratory in Fort Lauderdale, Fla. As time permitted, samples were thawed, and a technician inspected each piece of plant material under a dissecting microscope, removed any fauna, and placed it in 80 percent isopropyl alcohol in vials marked with the collection number. Twenty-five randomly chosen strands of hydrilla from each sample were rated for the amount of apparent feeding damage. Leaves and stems on each of the 25 strands were rated on a scale of 1 to 4, with 1 being no damage and 4 being severe damage. It was frequently difficult to interpret whether damage, especially severe damage, was due to feeding or to environmental factors such as low temperature, wave action, or other factors (e.g. toxins or herbicides). Hence, the damage ratings probably overestimate the amount of insect feeding damage.

The plants were sorted by species (if species other than hydrilla were present), all the fauna was removed, and the wet weight of each plant species was recorded. Several plant specimens from each collection were pressed and mounted on herbarium sheets to serve as voucher specimens. The plant samples were then dried to a constant weight and their dry weights recorded.

Insects were sorted into groups and identified. Merritt and Cummins (1978) was useful in identifying aquatic insects, especially the immature stages, to family level. Many families of insects could be identified to generic level using Pennak (1978) and Usinger (1956). Wiggins (1977) was excellent for identifying the genera of caddisfly larvae (Trichoptera). Simpson and Bode (1980), Mason (1973), and Beck (1977) were useful in identifying midge (Chironomidae) larvae to genus. Dragonfly (Odonata: Anisoptera) larvae, when large enough, usually could be identified to species level using Needham and Westfall (1954). This reference was the only one which had keys to all the U.S. species of this major group of aquatic insects. Species level determinations for other groups were very difficult. Regional, localized treatments for some taxa were helpful. Among the most noteworthy of these were: Berner (1950) for Florida mayflies (Ephemeroptera), Bobb (1974) for Virginia Hemiptera, Walker (1953) for the Canadian damselflies (Odonata), and Young (1954) for Florida beetles (Coleoptera). If not covered by these works, the insect could usually be identified only to genus. Dr. Dale Habeck, University of Florida, identified the aquatic moth (Lepidoptera) larvae.

The snails were identified to genus using the keys in Pennak (1978). Some snails from Florida could be identified to species using the descriptions found in Thompson (1968). Crustaceans and other invertebrates were identified using the keys in Pennak (1978) and Ward and Whipple (1959). Fish from Florida were keyed to species using Stevenson (1976).

All data, including species counts, gathered from July 1978 through July 1980 were entered into a computer for statistical analyses. Data from the quantitative

collections were graphed to show seasonal variation in plant biomass and faunal populations.

Determination of whether an insect was damaging hydrilla was based primarily on literature records, which were especially useful in excluding groups. This was supplemented by personal observation of actual feeding and by correlations between the density of a particular species and the damage to hydrilla.

Florida Collection Sites

During this study, 267 collections of hydrilla and its associated fauna were made at 58 different sites in Florida. These are listed in Appendix B. Most Florida collections were made using the special, quantitative sampler described earlier. However, if only a few hydrilla plants were present, or if weather conditions or bottom configuration prevented the use of the sampler, then the sample was collected by rake or anchor.

Figure 3 shows the distribution of the Florida collecting sites. Most sites were sampled several times during the course of the study, and thus each dot on the

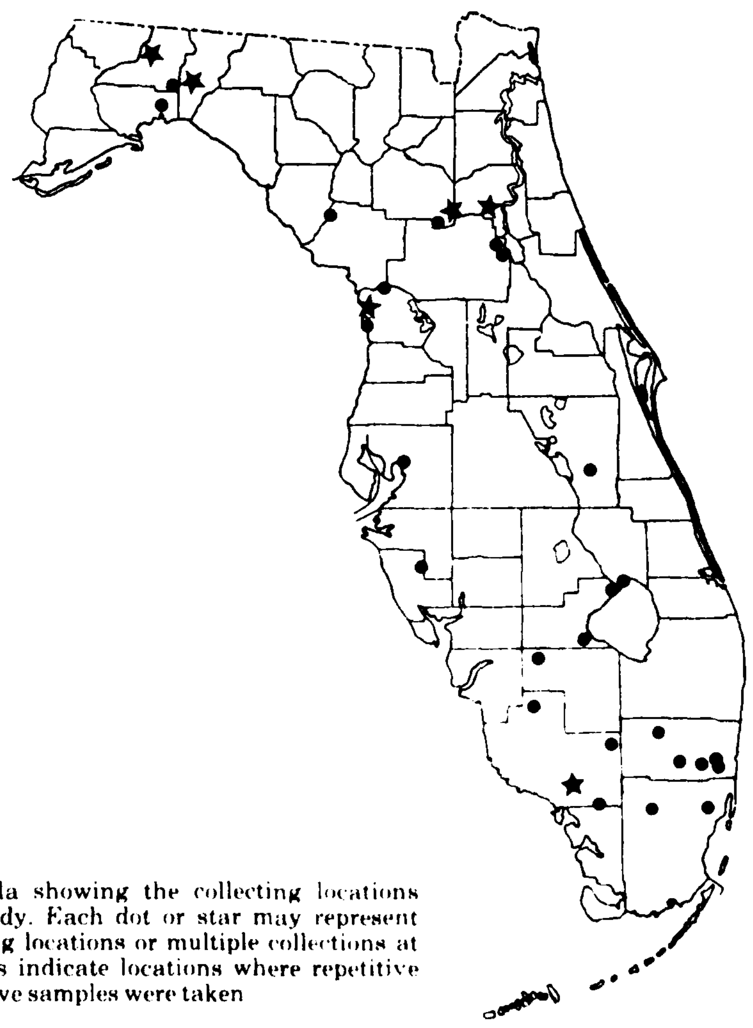


Figure 3. Map of Florida showing the collecting locations surveyed during this study. Each dot or star may represent several adjacent collecting locations or multiple collections at the same locations. Stars indicate locations where repetitive quantitative samples were taken

map frequently represents multiple collections. A single dot can also represent several, closely adjacent collecting sites. Many sites were sampled on a regular monthly schedule for most of the study period. Of these, six (depicted by stars in Figure 3) were selected for extensive analysis in this report. Unlike many other sites, all six sites maintained a significant hydrilla population throughout the study period (except for seasonal "declines" at some northern sites). These sites include an estuary (Crystal River); a clear, oligotrophic lake (Lake Jackson); a deeply colored, "swamp-water" lake (Lake Lochloosa); a recently formed, large, shallow reservoir (Rodman Reservoir); a spring-fed river (Wacissa River); and a south Florida drainage canal (SR 841 Canal). Brief descriptions of these six collecting areas follow, arranged from the northernmost (Lake Jackson) to southernmost (SR 841 Canal).

Lake Jackson. Located in Leon County, just to the north of Tallahassee, some 10 miles south of the Georgia border, Lake Jackson, during the survey period was approximately 1100 ha in size with a mean depth of 1.7 m (Langeland 1982). At the end of 1982, a sinkhole opened and drained all of Lake Jackson (Dr. K. Langeland, personal communication). This lake, along with being the northernmost of the monthly samples, was also the most oligotrophic, with exceptionally clear water with Secchi disk readings beyond the 3 m depth of the deeper portions of the lake. The hydrilla here never reached the surface during the study period, with the top strands saying below 1 m of the surface. The hydrilla here also was of an unusual growth form, having very slender stems with long, linear leaves. A copy of a herbarium sheet (Figure 4) vividly displays this growth form, especially when compared to "typical" hydrilla from another area (Figure 5). The sampling point was located along the western shore, near U.S. Route 27, in approximately 2.5 m of water.

Wacissa River. This medium-sized river in central Jefferson County, about 30 miles east of Tallahassee, is spring-fed and consequently has very clear water. The average flow is almost 400 cfs, and the water temperature remains a constant 21°C year-round. Hydrilla has become established in this river with the infestation being especially heavy near the head springs. The sampling site (Figure 6) was located in midriver, in about 1.5 m of water, about 1/4 mile downstream from the swimming area at Wacissa Springs.

Rodman Reservoir (Lake Ocklawaha). This large reservoir, over 5200 ha in surface area with a mean depth of 5.5 m, was formed in the late 1960s when the Ocklawaha River was dammed to form a pool to allow the operation of locks for the now-abandoned Cross-Florida Barge Canal. Although usually listed as Lake Ocklawaha on maps, to most people in northern Florida it is better known as Rodman Reservoir, and the latter name will be used throughout this report. The sample site was located about 1/4 mile from the Rodman Recreation Area boat ramp on the northeast side of the reservoir (Figure 7). The transparency of the water was highly variable ranging from 0.7 m to in excess of 2.5 m with the mode being 1.2 m.

Lake Lochloosa. Located on the southeast border of Alachua County, around 20 miles from Gainesville, Lake Lochloosa is a large lake with almost 2200

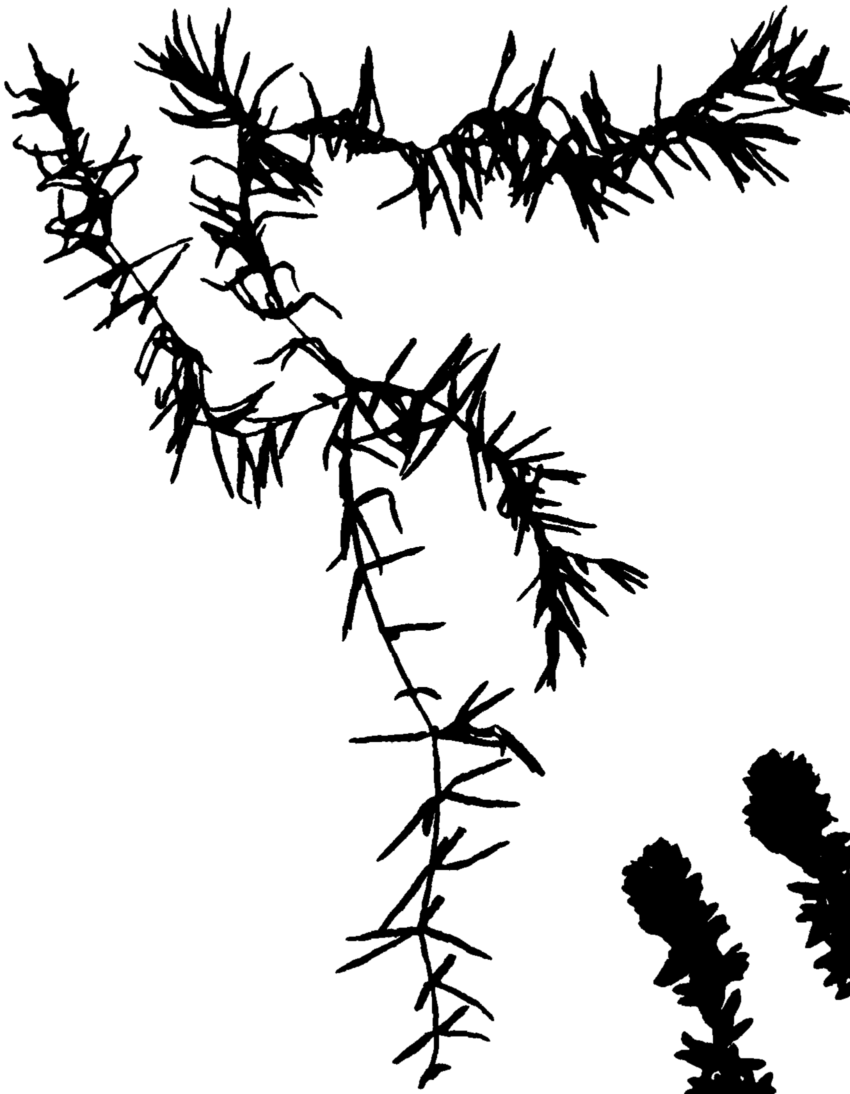


Figure 4. Photocopy of a hydrilla plant (herbarium specimen) from Lake Jackson showing the unusual growth form of this population. Note the thin stems and narrow leaves

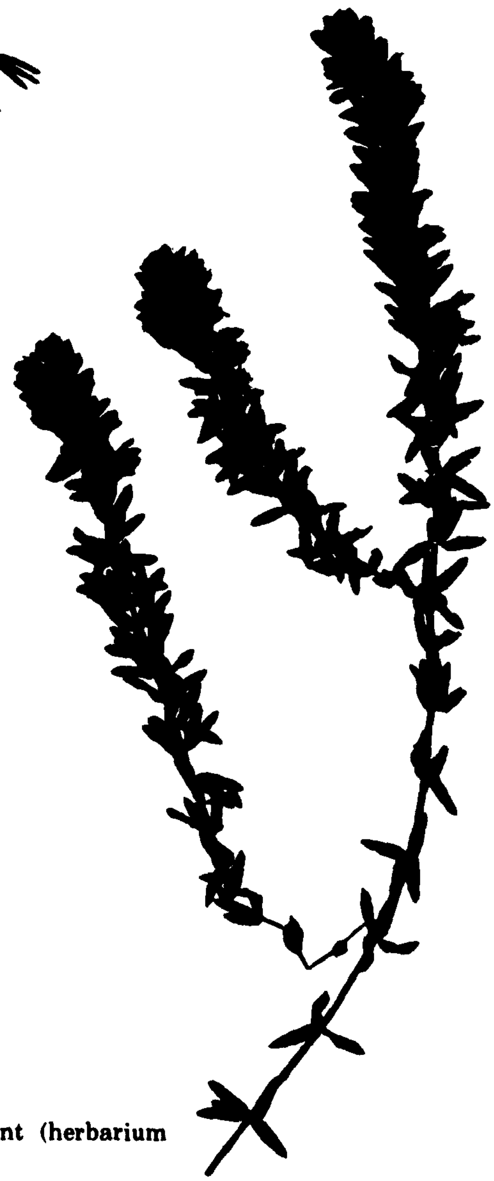


Figure 5. Photocopy of a typical hydrilla plant (herbarium specimen) from Rodman Reservoir

Figure 6. Hydrilla infestation at the Wacissa River in Jefferson County, Florida

Figure 7. Rodman Reservoir in Putnam County showing extensive growth of hydrilla and other aquatic macrophytes

surface acres (Heath and Conover 1981). Most of the shoreline is cypress swamp and the water is colored a dark red. The Secchi disk readings of water transparency ranged from 0.6 m to 1.5 m with a mean of 1.0 m. The collecting site was located at the southwest corner about 100 m from shore in water about 2.4 m deep.

Crystal River. Crystal River is a very broad, short river in Citrus County on Florida's west coast. It is formed by the combined flow (exceeding 900 cfs) of numerous freshwater springs, of which Crystal Springs is the largest. Water temperature is a constant 23°C. Being close to the Gulf of Mexico, most of the river is estuarine. The sample point was located near the mouth of Miller's Creek, in about 0.8 m of water. Salinity here, greatly influenced by the tides, ranged from 0 to 1.5 ppt averaging 0.5 ppt.

SR 841 Canal. This shallow (1.2 m deep), 10-m-wide canal (Figure 8) in Collier County was usually choked by lush growth of hydrilla and southern naiad (*Najas guadalupensis*). The sampling point was located at a footbridge, crossing the canal, 2.8 miles north of Tamiami Trail (U.S. Route 41), about 70 miles west of Miami. The water temperature here averaged 25.5°C, and at times exceeded 31°C.

Collection Sites Outside of Florida

In order to determine the effects of geographic variability on the insect fauna associated with hydrilla, infestations at four other states where hydrilla had been recorded (in 1979) were sampled. Two infestations near the Mexican border in California were sampled. In Georgia, five collections were made at Lake Seminole

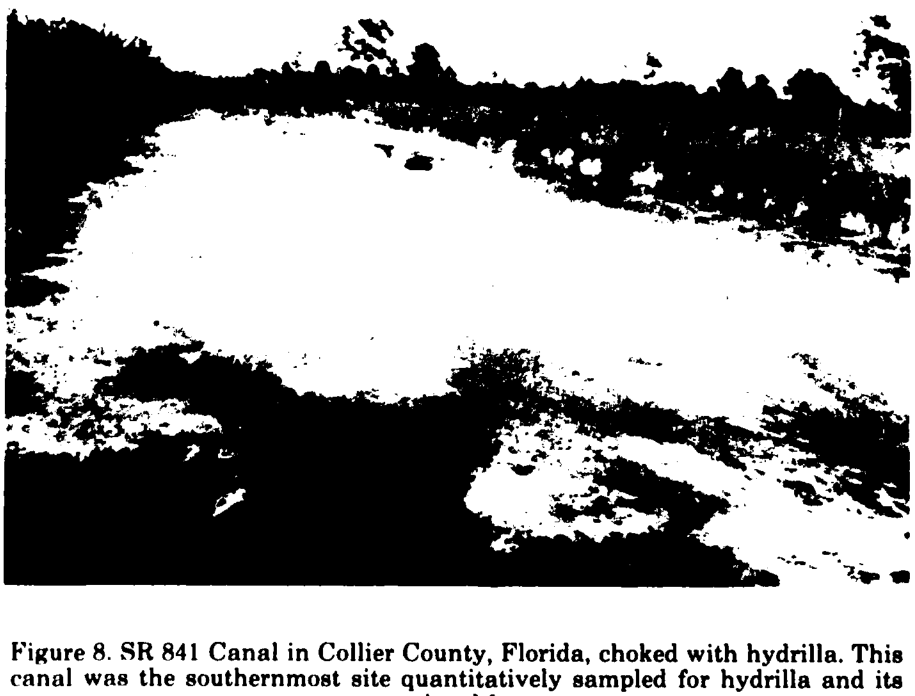


Figure 8. SR 841 Canal in Collier County, Florida, choked with hydrilla. This canal was the southernmost site quantitatively sampled for hydrilla and its associated fauna

and its vicinity. In southern Louisiana, two sites were sampled, while nine collections were made from infestations in central and east Texas. (See Appendix C for a complete list of non-Florida collections.)

Collections of hydrilla insects were also made during two trips to the Panama Canal, and these are included in the analysis.

Analyses

SAS. Computer files containing all the data from this study were created, stored, and modified, using a Digital PDP 11 computer at the University of Florida Agricultural Research and Education Center in Fort Lauderdale, Fla. For analysis, these files were transmitted via a telephone line to an AMDAHL 470 V/6 computer at the North East Regional Data Center (NERDC) at the main campus of the University of Florida at Gainesville. NERDC has available various data management and statistical analysis programs which are collectively known as SAS (Statistical Analysis System) and are detailed by Barr et al. (1976). Version 79.6 of SAS was used for the analyses. The most frequently used SAS procedures were standard descriptive statistics (PROC MEANS), correlation (PROC CORR), and data rearrangement (PROC SORT).

Species diversity. Species diversity was compared of the insects collected at Lake Jackson, Wacissa River, Lake Lochloosa, Rodman Reservoir, Crystal River, and SR 841 Canal. The species diversity, as expressed by the Shannon-Weaver diversity index, was calculated for each collection from each of the six sites. The Shannon-Weaver diversity index is the most widely used of the many diversity *indices employed in studies of biological communities.* This index is sensitive both to species richness (the number of species in the collection) and to species evenness (the distribution of specimens among the species). The Shannon-Weaver diversity index H′ is calculated according to the following algorithm (from Pielou 1966):

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where

s = total number of species in the collection

p_i = proportion of the total specimens comprised by the ith species or $p_i = n_i/N$

n_i = number of specimens in the ith species

N = total number of specimens in the collection

A modification of a Fortran program from Balciunas (1976, Appendix A) was used to perform the calculations of the diversity indices. This recently modified Fortran program is shown in Appendix D. The base for the logarithms used in the calculation of Shannon-Weaver index is left to the discretion of the researcher; this study uses natural logarithms (l_n or $\log_e$)

Species accumulation. As an indication of sampling efficiency, we graphically analyzed the species data from each of the six extensively studied sites and from all the Florida collections, by graphing the number of new species added by each subsequent collection from that site.

RESULTS

Appendix B lists the locations and dates for all 267 hydrilla collections in Florida, while Appendix C presents the same data for the 22 hydrilla collections from California, Georgia, Louisiana, Texas, and the Panama Canal.

Appendix E presents data describing the collection site parameters and those delineating the floral sample. Water depth, mat depth, water temperature, salinity, conductivity, and the wet and dry weights of each aquatic plant species in the sample are listed. Most earlier samples in 1978 are missing part or all of these data since test protocol had not been established. Other missing data are due to lack of measuring instruments when originals were being repaired or replaced. Also included in this appendix are average damage ratings for both leaves and stems for top, middle, and lower portions (six different ratings per collection) of 10 randomly chosen hydrilla strands from each collection.

The quantitative data for the six collection sites selected for more extensive examination and discussion are presented in Appendices F through K.

A summary of the insect taxa collected is included as Appendix L. A listing of the 28,490 snails collected and identified during this survey can be found in Appendix M. Appendix N presents a listing of the more than 11,000 invertebrates, other than insects and snails, which were collected and identified during this study. Appendix O lists the identifications of the 1437 fish collected in the Florida samples.

An annotated list of all 17,398 insects collected during this survey is presented in the following pages. Information about the relationship of each group to aquatic plants is noted. The total number of specimens of each species is given. Collection numbers where each species was collected are listed and the patterns of distribution noted. The orders of insects are arranged in evolutionary order, the more primitive insect orders first and the more highly evolved orders last, following the pattern of Merritt and Cummins (1978). Within the orders, the families are arranged alphabetically as are the genera and species found in each family. The species are numbered and an asterisk (*) appears before the species number if that particular species is thought to feed on hydrilla. An asterisk followed by a question mark (*?) precedes species considered possible feeders. Figures of all insects feeding on hydrilla are shown along with figures of the more abundant or important species in each insect order.

Order Ephemeroptera (Mayflies)

Some 414 mayflies were found in 92 hydrilla collections from 18 different sites in Florida. An additional 14 specimens in 5 collections were from 2 Texas sites and 4 specimens in 1 collection were from Rio Chagres, Panama. These 432 Ephemeroptera specimens represented only 2 percent of all insects collected. However, 34 percent of all collections contained mayflies, and mayflies were found at 36 percent of the sites sampled. Although at least 8 species of mayflies were taken, 96 percent of the specimens were either *Callibaetis floridanus* Banks

or *Caenis diminuta* Walker. Dr. Lewis Berner, Department of Zoology, University of Florida, confirmed most identifications.

The Ephemeroptera are a diverse group of hemimetabolous insects adapted to a wide variety of lotic and lentic aquatic habitats. Adult mayflies are short-lived terrestrial insects which do not feed. A few species are predaceous, but nymphs of most species feed on detritus and diatoms (Cummins and Edwards 1978). Pemberton (1980) found a few nymphs of *Povilla adusta* Navas (Polymitarcyidae) inside hydrilla stems at Lake Tanganyika in Eastern Africa. The nymphs of North America polymitarcyids excavate u-shaped burrows in river bottoms and feed on particles of detritus (Edmunds, Jenson, and Berner 1976). Mayfly nymphs probably utilize hydrilla plants as a substrate which conceals them from predators. They may also feed on decaying parts of the plants or on the microflora growing on leaf and stem surfaces.

- Family BAETIDAE

Baetids occupy a variety of aquatic habitats from hot springs to highly oxygenated riffle habitats in streams and rivers. *Callibaetis* species are adapted to lentic waters and are usually found in lakes and ponds.

1. *Callibaetis floridanus* Banks - 197 nymphs in 57 collections from 19 Florida sites: Broward Condo Lake, Caloosahatchee Tributary, Crystal River, Crystal River Canal, Homossasa Springs, Inglis Reservoir, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Myakka River, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Tamiami Canal, Tampa Fairground Ponds, and Wacissa River (collections 78206, 78209, 78212, 78227, 78228, 78234, 78248, 78251, 79268, 79274, 79276, 79284, 79287, 79295, 79298, 79301, 79319, 79321, 79322, 79327, 79329, 79336, 79339, 79341, 79342, 79350, 79352, 79356, 79365, 79366, 79367, 79369, 79394, 79399, 79400, 79401, 79404, 79406, 79410, 79411, 79413, 80201, 80202, 80203, 80207, 80212, 80213, 80214, 80217, 80225, 80251, 80254, 80257, 80260, 80262, 80266, and 80279). This species is often associated with hydrilla in Florida, comprising 46 percent of all mayflies collected. Balciunas (1977, 1982) also commonly found *C. floridanus* among waterhyacinth roots and *Myriophyllum spicatum* plants. *Callibaetis floridanus* was correlated with *Trichocorixa sexcinata* ($r = 0.527$, $p = 0.0001$, $n = 284$). Figure 9 shows a nearly mature *C. floridanus* nymph.
2. *Callibaetis* species A - 2 nymphs from Rio Chagres, Panama (collection 79312). No references are available to determine neotropical mayfly nymphs but these specimens are unlikely to be any North American species.
3. *Callibaetis* species B - 1 nymph from the San Marcos River, Texas (collection 80269). This specimen was too damaged to be identified to species; however, it seems to be distinct from *C. floridanus*.

Figure 9. A mayfly nymph, *Callibaetis floridanus* Banks (Ephemeroptera: Baetidae). The body length of this nearly mature nymph is 6.4 mm. *Callibaetis floridanus* nymphs comprised 46 percent of the 414 mayflies collected. Mayflies were found at 36 percent of the collection sites, but comprised only 2 percent of the insects collected on hydrilla. Most mayfly nymphs feed on detritus and algae

- Family CAENIDAE

Caenids are usually found in lakes, ponds, and in pools and sluggish areas of streams and rivers. Edmunds, Jensen, and Berner (1976) state that *Caenis* nymphs are often found on aquatic vegetation and list *Ruppia* as an example. Pearson and Jones (1978) collected a few *Caenis horaria* (L.) from *Potamogeton* in England.

4. *Caenis diminuta* Walker - 216 nymphs in 57 collections from 20 Florida sites: Broward Condo Lake, Caloosahatchee Tributary, Crystal River, Crystal River Canal, Holiday Park Canal, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Myakka River, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Tamiami Canal, Tampa Fairground Ponds, Wacissa River, and 72 Ave. Canal (collections 78209, 78211, 78212, 78214, 78217, 78224, 78227, 78228, 78243, 78251, 79260, 79264, 79272, 79274, 79275, 79277, 79279, 79286, 79287, 79290, 79296, 79321, 79331, 79333, 79339, 79348, 79356, 79366, 79369, 79375, 79394, 79401, 79406, 79408, 79410, 79411, 79412, 79413, 80203, 80207, 80210, 80213, 80214, 80215, 80216, 80222, 80223, 80226, 80228, 80229, 80236, 80239, 80249, 80256, 80261, 80267, and 80275).

Figure 10. A mayfly nymph in the family Caenidae, *Caenis diminuta* Walker. This species comprised 52 percent of all the mayflies found in association with hydrilla. The body length of this mature nymph is 4.3 mm

This species is commonly associated with hydrilla in Florida. Fifty-two percent of the mayflies collected in Florida were *C. diminuta*. It was the dominant mayfly found by Balciunas (1977, 1982) among water-hyacinth roots and *Myriophyllum spicatum* plants. A mature nymph is shown in Figure 10.

5. *Caenis* species A - 2 nymphs from Rio Chagres, Panama (collection 79312). No references are available to determine neotropical mayfly nymphs but these specimens are unlikely to be any North American species.

6. *Caenis* species B - 2 nymphs from Lake Conroe, Texas (collection 79378). The specimens were too decayed to identify beyond genus but are distinct from *C. diminuta*.

- Family LEPTOPHLEBIIDAE

7. *Leptophlebia bradleyi* Needham - 1 nymph from the Wacissa River, Florida (collection 78244). Leptophlebiids are often abundant on detritus in sluggish areas of streams and rivers. Dr. Berner (personal communication) says that *L. bradleyi* is a rare species and that its association with hydrilla is unusual.

• Family TRICORYTHIDAE

8. *Tricorythodes* species - 11 nymphs in 4 collections from the San Marcos River, Texas (collections 79377, 80269, 80270, and 80271). *Tricorythodes* nymphs are usually found in large streams and rivers. The nymphs are similar to *Caenis* in appearance and habit.

Order Odonata (Dragonflies and Damselflies)

In Florida, 1104 Odonata larvae were found in 173 hydrilla collections from 31 different sites. An additional 74 specimens were collected at 10 sites in California, Georgia, Texas, and Panama. The 383 dragonfly and 795 damselfly nymphs (1178 Odonata) represented 7 percent of all insects collected; 64 percent of the collections contained dragonflies or damselflies; and Odonata were found at 55 percent of the sites sampled, making this group the most widely represented group of all the insect orders.

A high number of Odonata taxa including 6 families, 23 genera, and approximately 34 species were collected. At least 22 species of dragonflies and 12 species of damselflies were found. In species richness (i.e., number of different species), the Odonata ranked second only to the Diptera, of the insect orders collected. However, the damselflies, *Enallagma signatum-pollutum* complex and *Ischnura posita* (Hagen), constituted 60 percent of all Odonata specimens. Ten nymphs were either an undescribed Panamian species or were too immature to identify beyond the family category.

Odonata nymphs are usually found in lentic habitats such as lakes, ponds, and pools of rivers and streams. Habitats most frequently colonized by Odonata tend to be permanent, unshaded waters which contain a variety of aquatic and semiaquatic plants (Corbet 1980). Both adults and nymphs are strictly predaceous (Cummins and Westfall 1978). Dragonfly and damselfly nymphs are probably associated with hydrilla because the plants shelter prey organisms and provide concealment from predators. Pemberton (1980) commonly found damselfly and dragonfly larvae on hydrilla plants in Eastern Africa. Corbet (1980) states that some species of Odonata lay their eggs within aquatic plants and that the type and distribution of aquatic vegetation, i.e. oviposition sites, may thereby influence Odonata population sizes and distributions. Both nymphal and adult Odonata may impact hydrilla by reducing populations of herbivores such as *Parapoynx* species.

Suborder Anisoptera (Dragonflies)

A total of 18 genera, 22 species, and 383 specimens of dragonflies were collected in association with hydrilla. Compared to damselflies, dragonflies were fewer in number but richer in genera and species. Thirty-three percent of all Odonata collected were Anisoptera.

• Family AESCHNIDAE

Aeschnid nymphs are active climbers on aquatic vegetation, branches, logs, and other underwater supports (Needham and Westfall 1954). However, only 5 specimens from Florida and 3 from Panama were taken in the present survey. The

family is widely distributed and contains approximately 37 North American species (Cummins and Westfall 1978).

9. *Anax junius* Drury - 4 nymphs in 4 collections from Crystal River, Lake Lochloosa, Rodman Reservoir, and Wacissa River (collections 79324, 79399, 79401, and 79406). A specimen of this species has been recorded from waterhyacinth roots in Florida (Balciunas 1977).
10. *Basiaeschna janata* Say - 1 larva taken in the St. Marks River, Florida (collection 79326).
11. Aeschnidae species A - 2 nymphs in 2 collections from Rio Chagres, Panama (collections 79312 and 80277). No references are available to determine neotropical Odonata nymphs but these specimens are unlikely to be any North American species.
12. Aeschnidae species B - 1 nymph from Rio Chagres, Panama (collection 79312). See Aeschnidae species A comments.

• Family CORDULIIDAE

Among the corduliids, 38 specimens comprising 2 genera and 4 species were found in our hydrilla collections. *Tetragoneuria cynosura* Say was the most abundant and the most frequently encountered corduliid. Corduliid nymphs are similar to libellulids in habit (Cummins and Westfall 1978).

13. *Epicordulia regina* Hagen - 10 nymphs in 7 collections from 6 Florida sites: Holiday Park Canal, Lake Hicpochee, Lake Lochloosa, SR 841 Canal, St. Marks River, and Wacissa River (collections 78222, 78243, 79268, 79300, 79304, 79355, and 80221).
14. *Tetragoneuria cynosura* Say - 24 nymphs in 16 collections from 6 Florida sites, Broward Condo Lake, Lake Jackson, Lake Trafford, Rodman Reservoir, SR 841 Canal, St. Marks River; and Lewis Pond, Georgia (collections (Fla.) 78245, 79292, 79305, 79322, 70325, 79338, 79345, 79357, 79362, 79363, 79366, 79410, 80232, 80257, 80262; and (Ga.) 79390). This species was one of the more common dragonflies, representing 6 percent of the Anisoptera collected. Nymphs of *T. cynosura* have also previously been collected among waterhyacinth roots (Balciunas 1977).
15. *Tetragoneuria semiaquez* Bermeister - 3 nymphs in 2 collections from Lake Jackson, Florida, and Lewis Pond, Georgia (collections (Fla.) 79305; (Ga.) 79390).
16. *Tetragoneuria sepia* Gloyd - 1 nymph from Lake Jackson, Florida (collection 80232).

• Family GOMPHIDAE

Only 1 species of gomphid was taken in the present survey. The scarcity of gomphids in the samples was probably due to the habit of the nymphs which, unlike most other Odonata, bury themselves in soft substrates and do not climb on vegetation. The family contains many widely distributed North American species (Cummins and Westfall 1978).

17. *Aphylla williamsoni* Gloyd - 1 nymph from Inglis Reservoir, Florida (collection 78248). This nymph was apparently stirred from the reservoir bottom when the sample was taken. Balciunas (1977) recorded a specimen on waterhyacinth.

- Family LIBELLULIDAE

There are more genera and species of Libellulids in North America than any other dragonfly family (Cummins and Westfall 1978). The family was well represented in the survey in that 11 genera, 14 species, and 336 specimens were taken (28 percent of all Odonata). The nymphs of some species are active climbers, others lie sprawled on rocks, logs, lake and pond bottoms, and other substrates (Needham and Westfall 1954). *Erythemis simplicicollis* Say was the most abundant libellulid taken. *Celithemis* species B and *E. simplicicollis* were the most frequently collected libellulids.

18. *Cannacria gravida* Calvert - 12 nymphs in 12 collections from 8 Florida sites: Broward Condo Lake, Crystal River Canal, Lake Lochloosa, Lake Trafford, Orange Lake, Rodman Reservoir, SR 841 Canal, and SW 76 Avenue Canal (collections 79264, 79268, 79277, 79300, 79303, 79322, 79357, 79399, 79411, 79414, 80201, and 80252).

19. *Celithemis* species A - 2 larvae in 2 collections from 2 Florida sites: Orange Lake and Tamiami Canal (collections 79356 and 80256). Needham and Westfall (1954) state that the nymphs of this genus live in submersed vegetation.

20. *Celithemis* species B - 56 nymphs in 30 collections from 8 Florida sites, Alligator Alley Canal, Broward Condo Lake, Crystal River Canal, Lake Johnson, Lake Trafford, Rodman Rservoir, SR 841 Canal, Tamiami Canal; and Lake Conroe, Texas (collections (Fla.) 78216, 78225, 79264, 79268, 79287, 79292, 79300, 79305, 79308, 79309, 79311, 79315, 79317, 79322, 79323, 79325, 79334, 79338, 79349, 79351, 79362, 79363, 79375, 79394, 79419, 80219, 80225, 80262, 80267; and (Tex.) 79378). This species was a common hydrilla associate, representing 15 percent of all dragonflies collected. See *Celithemis* species A discussion for nymphal habitat preferences. *Celithemis* species B was associated with *Erythemis simplicicollis* Say ($r = 0.545$, $p = 0.0001$, $n = 284$).

21. *Dythemis rufinervis* Burmeister - 8 nymphs in 8 collections from 6 Florida sites, Alligator Alley Canal, Crystal River Canal, Lake Jackson, Loop Road Canal, SR 841 Canal, SW 76 Avenue Canal; and Lewis Pond, Georgia (collections (Fla.) 78225, 79277, 79321, 79322, 79368, 80232, 80245; (Ga.) 79390).

22. *Erythemis simplicicollis* Say - 179 nymphs in 35 collections from 17 Florida sites, Alligator Alley Canal, Big Bass Lodge Canal, Broward Condo Lake, Crystal River, Crystal River Canal, Holiday Park Canal, Inglis Reservoir, Lake Lochloosa, Lake Trafford, Loop Road Canal, NW 25 Street Canal, Orange Lake, SR 841 Canal, St. Marks River, Tamiami Canal, Tampa Fairground Ponds, 72 Avenue Canal; the SR

Figure 11. A dragonfly nymph, *Erythemis simplicicollis* Say (Odonata: Libellulidae). This nymph has a body length of 32.5 mm. While dragonflies and damselflies were found at 55 percent of the sites sampled, only 7 percent of all insects found in association with hydrilla were Odonata. The most abundant dragonfly was *E. simplicicollis* which comprised 47 percent of the 383 nymphs collected. Both immature and adult dragonflies are predaceous

24 Canal in Louisiana; and Fish Hatchery Pond, Texas (collections (Fla.) 78206, 79210, 78211, 78214, 78217, 78221, 78224, 78225, 78231, 79255, 79264, 79286, 79288, 79290, 79311, 79322, 79326, 79332, 79334, 79345, 79348, 79349, 79356, 79362, 79363, 79366, 79369, 79375, 79398, 79410, 79412, 80212, 80275; (La.) 79381; and (Tex.) 79376). This was the most numerous dragonfly collected representing 47 percent of all Anisoptera. This species is also common in waterhyacinth roots (Balciunas 1977) and *Myriophyllum spicatum* plants (Balciunas 1982). *Erythemis simplicicollis* was associated with undetermined Tanypodinae species B ($r = 0.564$, $p = 0.0001$, $n = 284$), *Celithemis* species B ($r = 0.545$, $p = 0.0001$, $n = 284$), and *Liodessus flavicollis* ($r = 0.517$, $p = 0.0001$, $n = 284$). Figure 11 shows an *E. simplicicollis* nymph.

23. *Erythemis* species A - 2 nymphs from Rio Chagres, Panama (collection 79312). These specimens appeared to belong to the genus *Erythemis,* but no references were available to identify them to species.

24. *Erythrodiplax* species - 6 nymphs in 5 collections from 4 Florida sites, Holiday Park Canal, L Lake, NW 25 St. Canal, and SR 841 Canal (collections 78211, 78217, 78229, 79268, and 79334). Needham and Westfall (1954) state that the nymphs live in submersed vegetation.

25. *Libellula vibrans* Fabricius - 2 nymphs in 2 collections from 2 Florida sites, Loop Road Canal and SR 841 Canal (collections 79286 and 80251). The nymphs of this species lie sprawled on the bottoms of lakes and ponds (Needham and Westfall 1954).

26. *Macrodiplax balteata* Hagen - 9 nymphs in 7 collections from 4 Florida sites, Lake Trafford, Rodman Reservoir, SR 841 Canal, and St. Marks River (collections 78226, 79295, 79300, 79326, 79349, 79398, and 80212). Needham and Westfall (1954) state that the nymphs are sometimes found in slightly brackish waters.

27. *Miathyria marcela* Selys - 4 larvae in 4 collections from 3 Florida sites, Lake Trafford, NW 25 St. Canal, SR 841 Canal; and Rio Chagres, Panama (collections (Fla.) 78252, 79351, 79375; and (Panama) 80277). Balciunas (1977) collected this species from waterhyacinth roots.

28. *Pachydiplax longipennis* Bermeister - 46 nymphs in 15 collections from 6 Florida sites, Lake Hicopochee, Lake Jackson, Loop Rd. Canal, Orange Lake, SR 841 Canal, Turnpike Stream at 155-m marker; and Rio Chagres, Panama (collections (Fla.) 78222, 79254, 79290, 79300, 79305, 79310, 79317, 79344, 79348, 79398, 79409, 80205, 80232, 80262; and (Panama) 79312). This species comprised 12 percent of all Anisoptera collected. Balciunas (1977) commonly found it on waterhyacinth roots.

29. Libellulidae species A - 6 nymphs in 2 collections from Rio Chagres, Panama (collections 79312 and 80277). No references were available to determine neotropical Odonata nymphs, but these specimens are unlikely to be any North American species.

30. Libellidae species B - 2 nymphs from Rio Chagres, Panama (collection 79312). See Libellulidae species A.

Undetermined Libellulidae—

Two nymphs in 2 collections from 2 Florida sites, Lake Trafford and Tamiami Canal (collections 79332 and 79363). These specimens were too immature to identify beyond the family category.

Suborder Zygoptera (Damselflies)

A total of 5 genera, 12 species, and 795 specimens of damselflies were collected. Sixty-seven percent of all Odonata specimens collected were damselflies. Compared to dragonflies, damselflies were more abundant but represented fewer genera and species.

• Family CALOPTERYGIDAE

Only a few species of calopterygids occur in North America. The nymphs of most species occur in lotic habitats (Cummins and Westfall 1978).

31. *Hetaerina americana* (Fabricius) - 2 nymphs in 2 collections from the All American Canal, California, and the San Marcos River, Texas (collections (Calif.) 78236 and (Tex.) 79377).

- Family COENAGRIONIDAE

Approximately 93 species of coenagrionids are found in North America. The nymphs of most species are active climbers and are frequently associated with aquatic vegetation (Cummins and Westfall 1978). A total of 4 genera, 11 species, and 793 specimens (mostly of just 2 species) were found in the present survey.

32. *Argia apicalis* (Say) - 3 nymphs in 3 collections from 2 Florida sites, Caloosahatchee Tributary and St. Marks River (collections 78227, 79261, and 79326).

33. *Argia* species A - 1 nymph from the All American Canal, California (collection 78236).

34. *Argia* species B - 1 nymph from the All American Canal, California (collection 78236).

35. *Enallagma carunculatum* Morse - 6 nymphs in 2 collections from California, All American Canal and Sheldon Reservoir (collections 78236 and 78237).

36. *Enallagma signatum-pollutum* complex - 356 nymphs in 110 collections from 20 Florida sites, Broward Condo Lake, Crystal River, Crystal River Canal, Holiday Park Canal, Lake Hicpochee, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Myakka River, NW 25 St. Canal, Orange Lake, Rodman Reservoir, Salt Springs, SR 841 Canal, St. Marks River, Suwannee River, SW 76 Avenue Canal, Tamiami Canal, Wacissa River; from Lake Seminole and Lewis Pond, Georgia; and Lake Conroe, Texas (collections (Fla.) 78205, 78206, 78211, 78212, 78217, 78218, 78222, 78228, 78230, 78241, 79249, 78251, 79257, 79261, 79264, 79265, 79266, 79268, 79269, 79270, 79271, 79272, 79274, 79276, 79278, 79279, 79283, 79286, 79287, 79289, 79290, 79293, 79295, 79296, 79299, 79300, 79301, 79302, 79303, 79306, 79319, 79321, 79322, 79324, 79329, 79331, 79333, 79334, 79337, 79339, 79343, 79346, 79348, 79349, 79353, 79354, 79355, 79356, 79362, 79363, 79364, 79366, 79368, 79369, 79375, 79398, 79399, 79401, 79402, 79406, 79410, 79411, 79412, 80202, 80203, 80206, 80207, 80208, 80212, 80213, 80215, 80216, 80217, 80218, 80219, 89221, 80223, 80225, 80226, 80228, 80231, 80232, 80234, 80236, 80238, 80240, 80243, 80251, 80252, 80256, 80257, 80260, 80262, 80263, 80265, 80267, 80275; (Ga.) 78202, 79390; and (Tex.) 79378). Both *Enallagma signatum* (Hagen) and *Enallagma pollutum* (Hagen) were collected by Balciunas (1977) on waterhyacinth roots. These species are also likely to be associated with hydrilla. The nymphs differ only in minor characters and even mature nymphs are extremely difficult to identify. The collections listed above may contain either *E. signatum*, *E. pollutum*, or both species. This species complex

Figure 12. A damselfly in the family Coenagrionidae, *Enallagma signatum-pollutum* complex. The body length of this immature nymph is 19.7 mm. Nymphs of this species complex and those of another damselfly, *Ischnura posita* (Hagen), were equally abundant on hydrilla and together represented about 60 percent of all Odonata collected. Damselflies are strictly predaceous

represented 30 percent of all Odonata collected. An *E. signatum-pollutum* nymph is shown in Figure 12.

37. *Enallagma* species A - 3 nymphs from Rio Chagres, Panama (collection 79312). These specimens appear to belong to the genus *Enallagma,* but no references were available to identify them to species.

38. *Enallagma* species B - 3 nymphs in 3 collections from 2 Florida sites, St. Marks River and Wacissa River (collections 80221, 80233, and 80234).

39. *Enallagma* species C - 56 nymphs in 14 collections from 2 Florida sites, Lake Jackson and SR 841 Canal (collections 79272, 79281, 79292, 79305, 79338, 79354, 79365, 79388, 79404, 80205, 80219, 80232, 80245, and 80262). All but 1 of these specimens were from Lake Jackson. *Enallagma* species C was associated with *Dicrotendipes* species ($r = 0.74$, $p = 0.0001$, $n = 284$), *Dicrotendipes leucoselis* ($r = 0.776$, $p = 0.0001$, $n = 284$), *Ablabesmyia parajanta* ($r = 0.675$, $p = 0.0001$, $n = 284$), and *Dicrotendipes modestus* ($r = 0.540$, $p = 0.0001$, $n = 284$).

40. *Ischnura posita* (Hagen) - 357 nymphs in 96 collections from 21 Florida sites, Big Bass Lodge Canal, Broward Condo Lake, Crystal River, Crystal River Canal, Holiday Park Canal, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Marshy Lake 1 mile west

of U.S. 98 Junction, Myakka River, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, SW 76 Avenue Canal, Tamiami Canal, Tampa Fairground Ponds, Wacissa River, 72 Avenue Canal; from SR 24 Canal in Louisiana; Lake Conroe and Lake Livingston, Texas; and Rio Chagres, Panama (collections (Fla.) 78206, 78209, 78211, 78212, 78217, 78220, 78221, 78224, 78228, 78251, 79256, 79261, 79264, 79265, 79268, 79269, 79270, 79274, 79276, 79277, 79278, 79284, 79285, 79286, 79287, 79288, 79289, 79290, 79295, 79296, 79300, 79301, 79302, 79314, 79315, 79317, 79319, 79320, 79322, 79329, 79330, 79334, 79337, 79338, 79343, 79345, 79349, 79355, 79356, 79361, 79362, 79263, 79369, 79370, 79375, 79383, 79394, 79398, 79399, 79400, 79401, 79405, 79406, 79409, 79413, 80201, 80202, 80203, 80205, 80207, 80208, 80212, 80213, 80215, 80216, 80217, 80218, 80219, 80225, 80226, 80228, 80239, 80240, 80242, 80248, 80249, 80252, 80259, 80262, 80265, 80267, 80275; (La.) 79381; (Tex.) 79378, 79380; and (Panama) 79312). This species represented 30 percent of all Odonata collected. Balciunas (1977) found *I. posita* to be one of the most abundant and most frequently encountered insects on Waterhyacinth roots. *Ischnura posita* and *E. signatum-pollutum* complex were of equal abundance and both were frequently collected in the present survey. These species were among the insects most frequently associated with hydrilla. *Ischnura posita* was associated with *Parachironomus monochromus* ($r = 0.548$, $p = 0.0001$, $n = 284$).

41. *Nehalennia* species A - 2 larvae in 2 collections from 2 Florida sites, St. Marks River and Suwannee River (collections 78205 and 79273).

42. *Nehalennia* species B - 5 larvae from 2 collections on the San Marcos River, Texas (collections 79377 and 80269).

Order Homoptera

- Family APHIDAE (Aphids)

* 43. Probably *Rhopalosiphum nymphaeae* (Linnaeus) - 4 adults in 2 collections from the Wacissa River, Florida, and the SR 24 Canal in Louisiana (collections (Fla.) 80254 and (La.) 79381). Aphids are terrestrial insects which feed on plant juices. *Rhopalosiphum nymphaeae* feeds on a wide variety of aquatic plants (Gaevskaya 1969) including emersed parts of *Myriophyllum spicatum* (Balciunas 1982) and hydrilla. Although aphids do little direct damage to hydrilla, their feeding punctures may serve as entrances for pathogenic plant fungi and bacteria. Positive identification of these adults could not be made due to the poor condition of the specimens.

Order Hemiptera (True Bugs)

A total of 573 Hemiptera represented 3 percent of all insects collected; 33 percent of the collections contained Hemiptera; and Hemiptera were found at 39 percent

of the sites sampled. Five hundred and sixty-one immature and adult Hemiptera were found in 91 hydrilla collections from 26 Florida sites. Another 5 specimens were from 2 collections at 2 Texas sites and 7 specimens were from Rio Chagres, Panama.

Nine families, 11 genera, and 14 species of Hemiptera were collected in association with hydrilla. Most of the corixids were identified by Dr. Reece I. Sailer, Department of Entomology, University of Florida. Dr. T. J. Henry, Systematic Entomology Laboratory, Insect Identification and Beneficial Insect Introduction Institute, USDA, confirmed the identifications of a few species and all genera of the remaining families. *Trichocorixa* species and *Pelocoris femoratus* (Palisot de Beauvois) were the most abundant and frequently encountered species.

Typically, both mature and immature stages of the Hemiptera occupy the same habitats and utilize similar or the same food resources. Thus, both nymphal and adult stages were represented in our collections. Nearly all species of aquatic and semiaquatic Hemiptera are predaceous (Cummins and Polhemus 1978), but at least a few North American corixid species are known to feed, in part, on diatoms and the cellular contents of filamentous algae (Usinger 1956). Since semiaquatic Hemiptera generally occupy the water-air interface of lentic habitats, these species can only associate with topped-out hydrilla or floating pieces of the plant. Under such circumstances, hydrilla may harbor prey organisms on which these insects feed and offers a solid support on which to rest, mate, or oviposit. Aquatic species, which spend much of their lives totally submersed, may also find food and shelter on submerged hydrilla.

- Family BELOSTOMATIDAE (Giant Water Bugs)

Belostomatids are large, aquatic hemipterans usually found in ponds, lakes, and lentic habitats of streams and rivers. Their diet includes aquatic insects, other arthropods, amphibians, and fish (Usinger 1956). These predaceous insects may impact hydrilla by reducing populations of herbivorous aquatic arthropods and fish. Belostomatids represented 5 percent of all Hemiptera collected.

44. *Belostoma lutarium* (Stal) - 27 nymphs and adults in 21 collections from 14 Florida sites, Alligator Alley Canal, Big Bass Lodge Canal, Crystal River, Holiday Park Canal, Lake Hicpochee, Lake Trafford, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, Tamiami Canal, Wacissa River; and Fish Hatchery Pond, Texas (collections (Fla.) 78221, 78222, 78225, 78235, 78243, 79217, 79288, 79291, 79300, 79320, 79336, 79339, 79348, 79349, 79353, 79369, 79375, 79395, 80260, 80265; and (Tex.) 79376). Balciunas (1977) took specimens of this species and *Belostoma testaceum* (Leidy) on waterhyacinth roots. Eight of the belostomatids associated with hydrilla were adult *B. lutarium*. No references are available to identify nymphs. Our nymphs may be either *B. lutarium* or *B. testaceum*. Only a few belostomatids were taken by Balciunas (1982) on *Myriophyllum*.

- Family CORIXIDAE (Water Boatmen)

A total of 2 genera, 3 species, and 376 specimens of corixids were found in association with hydrilla. Sixty-seven percent of all Hemiptera in the collections were *Trichocorixa* species. Thirty-five nymphs could not be identified to species and two specimens could only be determined to family.

Balciunas (1977, 1982) took a few corixids on waterhyacinth roots and *Myriophyllum spicatum* plants. Hungerford (1948) and Usinger (1956) state that corixids feed on filamentous and unicellular algae, as well as small animals such as protozoans, rotifers, and early instar culicids and chironomids. Some species of corixids prefer habitats rich in aquatic vegetation, whereas others inhabit open water (Bobb 1974).

45. *Sigara sigmoidea* (Abbott) - 1 adult from SR 841 Canal, Florida (collection 79300). Hungerford (1948) places this species in the subgenus *Phaeosigara*. Cummins and Polhemus (1978) list *Sigara* species as piercers - herbivores (on algae?).

Undetermined *Sigara* species—

Only 2 nymphs in 2 collections from 2 Florida sites, Lake Trafford and Rodman Reservoir (collections 79401 and 79411).

46. *Trichocorixa minima* (Abbott) - 15 nymphs and adults in 22 collections from 7 Florida sites, Inglis Reservoir, Lake Lochloosa, Lake Trafford, Orange Lake, Rodman Reservoir, SR 841 Canal, and Wacissa River (collections 78206, 78218, 78226, 78231, 79265, 79276, 79284, 79295, 79311, 79322, 79324, 79334, 79349, 79356, 79361, 79400, 79411, 80202, 80214, 80217, 80218, and 80262). This species constituted 26 percent of all hemipterans collected. Cummins and Polhemus (1978) note that *Trichocorixa* species are predaceous and often occur in saline waters.

47. *Trichocorixa sexcincta* (Champion) - 187 nymphs and adults in 26 collections from 8 Florida sites, Crystal River, Crystal River Canal, Lake Lochloosa, Lake Trafford, Orange Lake, Rodman Reservoir, SR 841 Canal, and Wacissa River (collections 79264, 79265, 79268, 79276, 79284, 79295, 79322, 79324, 79334, 79339, 79352, 79364, 79387, 79400, 79403, 79406, 79410, 79411, 80202, 80218, 80228, 80246, 80254, 80260, 80264, and 80265). *Trichocorixa sexcincta* was the most abundant hemipteran in the hydrilla collections, representing 33 percent of all true bugs found. This species was associated with *Callibaetis floridanus* ($r = 0.527$, $p = 0.0001$, $n = 284$). An adult *T. sexcincta* is shown in Figure 13.

Undetermined *Trichocorixa* species—

A total of 33 nymphs and adults in 15 collections from 7 Florida sites, Broward Condo Lake, Lake Trafford, Myakka River, Orange Lake, Rodman Reservoir, SR 841 Canal, and Wacissa River (collections 78250, 78251, 78259, 79287, 79322, 79356, 79375, 79387, 79400, 79401, 79403, 79411, 80213, 80265, and 80267). No references were available to identify corixid nymphs.

Figure 13. An adult water boatman, *Trichocorixa sexcincta* (Champion) (Hemiptera: Corixidae). This water boatman has a body length of 4.5 mm. Hemiptera were found at 39 percent of the sites sampled but represented only 3 percent of all insects collected. *Trichocorixa sexcincta* was the most abundant hemipteran taken, comprising 33 percent of all true bugs found in association with hydrilla. Most aquatic and semiaquatic Hemiptera are predaceous, although a few corixids may feed on algae

Undetermined Corixidae—

Only 2 nymphs in 2 collections from the SR 841 Canal and the Wacissa River, Florida (collections 79324 and 79334), were too immature to identify to genus.

• Family GERRIDAE (Water Striders)

Gerrids are semiaquatic, predaceous Hemiptera that skate on the surface of lentic waters. Only 2 genera, 2 species, and 17 specimens were found in association with hydrilla.

48. *Limnogonus hesione* (Kirkaldy) - 5 adults in 3 collections from the SR 841 Canal, Florida (collections 79334, 79349, and 80251). Balciunas (1977) took 1 specimen on waterhyacinth. Bobb (1974) says that *L. hesione* prefers sheltered places near the shore of ponds and lakes. This is the only North American species in the genus (Cummins and Polhemus 1978).

49. *Trepobates* species - 12 nymphs and adults in 5 collections from 2 Florida sites, SR 841 Canal and Tamiami Canal (collections 79322, 79349, 79373, 79398, and 80251). Eight species of *Trepobates* occur in North America and more than one species may be represented in the collections listed above. Balciunas (1977) took a specimen on waterhyacinth. This genus prefers habitats similar to those used by *L. hesione* (Bobb 1974).

- Family HEBRIDAE (Velvet Waterbugs)

50. *Merragata brunnea* Drake - 20 nymphs and adults in 7 collections from 6 Florida sites, Big Bass Lodge Canal, Broward Condo Lake, Lake Trafford, SR 837 Canal, SR 841 Canal, and Tampa Fairground Ponds (collections 78209, 78210, 78215, 78221, 79322, 79345, and 79351). *Merragata* is a small but widely distributed genus of predaceous, semiaquatic insects. Most species are found near the shores of lakes and ponds (Cummins and Polhemus 1978). Balciunas (1977) took a few specimens on waterhyacinth roots.

- Family MESOVELIIDAE (Water Treaders)

A small group of semiaquatic Hemiptera, this family is represented in North America only by the Genus *Mesovelia*. These predaceous insects live on floating and emergent vegetation growing in ponds and lakes (Bobb 1974).

51. *Mesovelia amoena* Uhler - 1 nymph from the Wacissa River and 1 adult from Lake Lochloosa, Florida (collections 80265 and 80275). Dr. Henry confirmed identification of this species. Balciunas (1977) took nymphs of this species on waterhyacinth.

52. *Mesovelia mulsanti bisignata* Uhler - 10 adults in 7 collections from 6 Florida sites, Broward Condo Lake, Caloosahatchee Tributary, Holiday Park Canal, Rodman Reservoir, SR 841 Canal, and Wacissa River (collections 78227, 78243, 79268, 79336, 79339, 79362, and 80265). Three specimens were confirmed by Dr. Henry. This species has also been taken on waterhyacinth (Balciunas 1977).

- Family NAUCORIDAE (Creeping Water Bugs)

Two species and 99 specimens of *Pelocoris* were taken in the present survey. *Pelocoris femoratus* represented 16 percent of all Hemiptera in the hydrilla collections. These insects are aquatic predators (Merritt and Cummins 1978).

53. *Pelocoris balius* La Rivers - 4 nymphs and adults in 2 collections from 2 Texas sites, Fish Hatchery Pond and San Marcos River (collections 79376 and 79377). This taxon is usually treated as a subspecies of *P. femoratus*; however, Balciunas (1977) often collected both taxa together on waterhyacinth which suggests that these taxa may be distinct species.

54. *Pelocoris femoratus* (Palisot de Beauvois) - 95 nymphs and adults in 37 collections from 10 Florida sites, Holiday Park Canal, Homossasa Springs, Lake Lochloosa, Lake Trafford, Loop Road Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, Tamiami Canal, Wacissa River, and Rio Chagres, Panama (collections (Fla.) 78206, 78217, 78218, 78226, 78243, 79253, 79286, 79288, 79290, 79297, 79300, 79301, 79308, 79309, 79315, 79316, 79321, 79324, 79327, 79337, 79339, 79343, 79348, 79349, 79350, 79351, 79352, 79355, 79363, 79364, 79375, 79398, 80251, 80255, 80260, 80262; and (Panama) 79312). A few of these specimens may be *P. balius*. *Pelocoris femoratus* was one of the most

Figure 14. An adult creeping water bug, *Pelocoris femoratus* (Palisot de Beauvois) (Hemiptera: Naucoridae); body length = 2.3 mm. This species represented 16 percent of all true bugs associated with hydrilla

abundant and frequently collected hemipterans on hydrilla. Figure 14 shows an adult *P. femoratus*.

• Family NEPIDAE (Water Scorpions)

Only one species of water scorpion was found in association with hydrilla. Balciunas (1977) also found *Ranatra australis* Hungerford and *Ranatra nigra* Herrich-Schaeffer on waterhyacinth. Nepids are aquatic, predaceous insects that occur in detritus and aquatic vegetation (Bobb 1974).

55. *Ranatra buenoi* Hungerford - 15 nymphs and adults in 9 collections from 6 Florida sites, Lake Lochloosa, Lake Trafford, Loop Road Canal, Orange Lake, Rodman Reservoir, and SR 841 Canal (collections 78206, 78226, 78235, 79268, 79290, 79299, 79302, 79337, and 80214). Five specimens of this species were confirmed by Dr. Henry.

• Family PLEIDAE (Pigmy Back Swimmers)

Pleids are small, aquatic hemipterans usually found among aquatic plants in lentic waters (Bobb 1974). Cummins and Polhemus (1978) state that the preferred prey are microcrustacea.

56. *Neoplea striola* Fieber - 1 adult from the Tampa Fairground Ponds, Florida (collection 78209). The specimen identification was confirmed by Dr. Henry. Balciunas (1977, 1982) took this species on waterhyacinth and *Myriophyllum*.

- Family VELIIDAE (Broad-Shouldered Water Striders)

Veliids are predaceous, semiaquatic Hemiptera which resemble gerrids in habit and appearance.

57. *Microvelia hinei* Drake - 2 adults from the SW 76 Avenue Canal, Florida (collection 78212). Bobb (1974) states that this species is found near the shores of ponds and lakes.

Order Neuroptera

- Family SISYRIDAE (Spongillaflies)

58. *Climacia* species - 2 larvae in 2 collections from the St. Marks River and Tamiami Canal, Florida (collections 79282 and 79373). Spongillaflies are a small, widespread group of aquatic Neuroptera. The larvae usually feed on freshwater sponges although Usinger (1956) states that they have been observed feeding on Bryozoa and algae in the vicinity of sponges. These specimens may have been dislodged from sponge colonies when the hydrilla collections were taken.

Order Trichoptera (Caddisflies)

A total of 4261 larvae, pupae, and teneral adults were found in 150 hydrilla collections from 20 Florida sites. Additionally, 1 specimen was taken at the All American Canal, California; 3 specimens were from 2 collections at 2 Georgia sites; and 20 specimens were from 6 collections at 3 Texas sites. A total of 4265 caddisflies represented 24 percent of all insects collected; 55 percent of the collections contained caddisflies; and Trichoptera were found at 35 percent of the sites sampled.

Eight families, 16 genera, and approximately 22 species of caddisflies were taken in the present survey. Hydroptilids and leptocerids represented 99 percent of all Trichoptera collected. *Orthotrichia* species and *Leptocerus americanus* (Banks) were the most abundant species found in the hydrilla collections. The most frequently collected caddisfly was *Orthotrichia* species. Only six adults and pupae could not be identified to genus or species. Eight immature larvae and pupae could not be determined to family.

Larval and pupal Trichoptera are found in both lotic and lentic aquatic habitats. The larvae often construct protective cases of vegetation, sand, and other materials. The last instar case often serves as a cocoon after slight modification and attachment to a substrate. Depending on the species, Trichoptera larvae may be herbivorous on algae and vascular plants, predaceous on small arthropods, or omnivorous, feeding on both plant and animal material. Herbivorous species taken in the present survey that may feed on hydrilla include *Leptocerus americanus, Nectopsyche tavara, Oecetis* species, and *Triaenodes* species. Although adult Trichoptera are terrestrial, our collections contained some specimens of teneral adults which emerged from pupae after these samples had been taken.

• Family HELICOPSYCHIDAE

59. *Helicopsyche* species - 4 larvae from the San Marcos River, Texas (collection 80272). Helicopsychids build distinctive cases which resemble snail shells. The larvae are usually found in lotic aquatic habitats. Larval feeding observations are few, but some species feed on algae, detritus, and animal materials (Wiggins 1977).

• Family HYDROPSYCHIDAE

60. *Cheumatopsyche* species - 1 larva from a tributary of the Caloosahatchee River, Florida (collection 78227). Hydropsychids are usually found in running waters, although Marcus (1981) found a few *Hydropsyche* species in submerged weeds at Conesus Lake, New York. Unlike most caddisflies, the larvae do not build cases but live in sheltered places such as in the cracks between rocks, under loose bark of logs, etc. Detritus, algae, and small aquatic invertebrates are filtered from the water with nets spun by the larvae (Wiggins 1977).

• Family HYDROPTILIDAE

Hydroptilids are very small caddisflies which inhabit lentic and lotic aquatic habitats throughout North America. The last instar larvae construct purselike cases of silk (Cummins and Wiggins 1978). Many species have been reported to feed on filamentous algae (Wiggins 1977). Approximately 4 genera and 8 species of hydroptilids were found in association with hydrilla. Hydroptilids represented 47 percent of all caddisflies collected.

61. *Hydroptila* species - 1 larva from Rodman Reservoir, Florida (collection 80263). Balciunas (1982) took 1 specimen of *Hydroptila* from the Crystal River. Blickle (1962) found 8 species of *Hydroptila* in Florida of which *H. maculata* (Banks), *H. wakulla* Denning, and *H. waubesiana* Betton were the most common.

62. *Ochrotrichia* species A - 23 pupae in 2 collections from the San Marcos River, Texas (collections 80269 and 80272). *Ochrotrichia* larvae live in lotic waters. Some species feed on diatoms (Wiggins 1977). The genus is mainly western in distribution.

63. *Ochrotrichia* species B - 1 pupa from the San Marcos River, Texas (collection 80272). See *Ochrotrichia* species A for discussion of larval habits.

64. *Orthotrichia* species - 1770 larvae, pupae, and teneral adults in 89 collections from 17 Florida sites, Broward Condo Lake, Crystal River, Crystal River Canal, Homossasa Springs, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Myakka River, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, Tamiami Canal, Wacissa River, 72 Ave. Canal; and Lake Seminole, Georgia (collections (Fla.) 78208, 78218, 78224, 78230, 78234, 78235, 78247, 78250, 78251, 79255, 79257, 79259, 79260, 79268,

Figure 15. A microcaddisfly larva (body length = 2.3 mm) and case, *Orthotrichia* species (Trichoptera: Hydroptilidae). Caddisflies were found at 35 percent of the sites sampled and comprised 24 percent of all hydrilla insects. *Orthotrichia* species was the most abundant caddisfly taken comprising 42 percent of the 4265 specimens collected. Hydroptilids feed on algae

79278, 79279, 79281, 79283, 79289, 79291, 79292, 79294, 79296, 79302, 79303, 79307, 79313, 79314, 79315, 79333, 79337, 79339, 79341, 79342, 79243, 79350, 79351, 79352, 79354, 79355, 79356, 79363, 79368, 79369, 79372, 79375, 79394, 79399, 79400, 79401, 79404, 79405, 79412, 80201, 80205, 80207, 80208, 80209, 80213, 80214, 80215, 80216, 80217, 80218, 80219, 80221, 80227, 80228, 80229, 80234, 80235, 80239, 80240, 80241, 80242, 80243, 80245, 80252, 80253, 80255, 80259, 80260, 80262, 80263, 80264, 80266, 80274, 80275; and (Ga.) 79389). Wiggins (1977) reports that the larvae occur in lentic waters in beds of aquatic plants and feed on filamentous algae. *Orthotrichia* species was the most numerous and frequently collected caddisfly associated with hydrilla representing 42 percent of all Trichoptera collected. Balciunas (1982) found *Orthotrichia* species to be the most abundant and frequently collected caddisfly on *Myriophyllum spicatum* as well. Blickle (1962) found 6 species of *Orthotrichia* in Florida of which *O. americana* Banks was the most common. *Orthotrichia* species was associated with *Parachironomus* species ($r = 0.501$, $p = 0.0001$, $n = 284$) in the present survey. A mature larva is shown in Figure 15.

65. *Oxyethira* species A - 10 larvae and pupae in 3 collections from Lake Lochloosa and Orange Lake, Florida (collections 79400, 80217, and 80275). *Oxyethira* larvae are usually found in beds of aquatic plants in lentic habitats. Filamentous and unicellular algae are the reported larval hosts (Wiggins 1977). Balciunas (1982) found a few *Oxyethira* larvae on *Myriophyllum spicatum* plants in Texas. Kobylinski (1980) also found *Oxyethira* larvae on *Myriophyllum* in Florida. Blickle (1962)

took 9 species of *Oxyethira* in Florida of which *O. glasa* Ross and *O. walteri* Denning were the most common. Four species of *Oxyethira* were taken in the present survey. The bottle-shaped cases of each of these species are distinct.

66. *Oxyethira* species B - 63 larvae and pupae in 15 collections from 7 Florida sites, Broward Condo Lake, Crystal River Canal, Loop Rd. Canal, NW 25 St. Canal, Rodman Reservoir, SR 841 Canal, and Tamiami Canal (collections 79328, 79405, 79410, 80208, 80209, 80213, 80216, 80222, 80223, 80231, 80235, 80239, 80250, 80262, and 80263).

67. *Oxyethira* species C - 3 pupae from Lake Conroe, Texas (collection 79379).

68. *Oxyethira* species D - 121 larvae and pupae in 18 collections from 3 Florida sites, Lake Jackson, SR 841 Canal, Tamiami Canal; Lewis Pond, Georgia; and the San Marcos River, Texas (collections (Fla.) 79260, 79268, 79272, 79281, 79285, 79338, 79354, 79365, 79388, 79404, 80205, 80212, 80219, 80232, 80249, 80256; (Ga.) 79390; and (Tex.) 80272). This species of *Oxyethira* was associated with *Dicrotendipes modestus* (4 = 0.695, p = 0.0001, n = 284), *Oecetis inconspicua* (r = 0.660, p = 0.0001, n = 284), *Enallagma* species C (r = 0.660, p = 0.0001, n = 284), *Dicrotendipes* species (r = 0.559, p = 0.0001, n = 284), and *Ablabesmyia parajanta* (r = 0.557, p = 0.0001, n = 284) in the present survey.

Undetermined Hydroptilidae—

Six pupae and teneral adults in 6 collections from 3 Florida sites, Lake Jackson, Rodman Reservoir, Suwannee River; the All American Canal, California; Lake Seminole, Georgia; and the San Marcos River, Texas (collections (Fla.) 78204, 79281, 79401; (Calif.) 78236; (Ga.) 79389; and (Tex.) 80272.

- Family LEPTOCERIDAE

Letocerids are medium-sized caddisflies commonly found in lakes, ponds, and lentic areas of streams and rivers (Wiggins 1977). The larvae build cases from a variety of materials. Some species feed, at least in part, on aquatic plants (McGaha 1952). Five genera, 6 species, and 2240 specimens of leptocerids representing 52 percent of all Trichoptera collected were found in association with hydrilla. *Leptocerus americanus* (Banks) was the most abundant leptocerid taken. The most frequently collected leptocerids were *Leptocerus americanus, Nectopsyche tavara,* and *Oecetis* species near *cinerascens* (Hagen).

69. *Ceraclea* species—4 larvae in 4 collections from 3 Florida sites: Rodman Reservoir, SR 841 Canal, and Tamiami Canal (collections 80210, 80214, 80251, and 80262). Larvae of many species of *Ceraclea* reportedly feed on detritus although some species eat freshwater sponges (Wiggins 1977).

*? 70. *Leptocerus americanus* (Banks) - 1593 larvae, pupae, and teneral adults in 38 collections from 9 Florida sites, Lake Jackson, Lake Lochloosa, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, SW 76

Figure 16. A leptocerid caddisfly larva (body length = 8.4 mm) and case, *Leptocerus americanus* (Banks). This species represented 37 percent of all caddisflies found in association with hydrilla. Larvae of *L. americanus* feed in part on aquatic vascular plants, possibly including hydrilla

Ave. Canal, Tamiami Canal, and Wacissa River (collections 78250, 79265, 79272, 79276, 79277, 79279, 79284, 79291, 79295, 79296, 79302, 79303, 79305, 79308, 79315, 79327, 79336, 79338, 79366, 79367, 79394, 79401, 79403, 79404, 80203, 80205, 80214, 80219, 80221, 80228, 80229, 80232, 80240, 80245, 80253, 80258, 80262, and 80266). This species represented 37 percent of all caddisflies found in association with hydrilla. Balciunas (1982) took larvae of *L. americanus* on *Myriophyllum* in Wisconsin and Wiggins (1977) noted that the larvae are often abundant on *Ceratophyllum.* Wiggins also mentions that *L. americanus* larvae have modified mesothoracic legs which may aid in grasping aquatic plants. The larvae from some populations are known to feed on aquatic vegetation (McGaha 1952); however, Wiggins (1977) found fine particulate matter (detritus?) in the guts of 3 larvae. *Leptocerus americanus* larvae may at least partially eat hydrilla although this species is likely to be omnivorous in feeding habit. The trumpet-shaped larval case is composed entirely of silk. Figure 16 shows a mature *L. americanus* larva and case.

* 71. *Nectopsyche tavara* (Ross) - 440 larvae and pupae in 32 collections from 8 Florida sites, Crystal River, Crystal River Canal, Lake Jackson, Lake Trafford, Rodman Reservoir, SR 841 Canal, St. Marks River, and Tamiami Canal (collections 78245, 78250, 79263, 79265, 79273, 79275, 79276, 79282, 79283, 79284, 79295, 79296, 79301, 79315, 79323, 79326, 79327, 79366, 79367, 79394, 79401, 79410, 79411, 80203, 80214, 80229, 80240, 80253, 80256, 80258, 80263, and 80266). Ten percent of all caddisflies collected were *Nectopsyche tavara.* The larvae feed on a wide variety of aquatic macrophytes, including hydrilla (Daigle and Haddock 1981). The trumpet-shaped larval case is composed of sand grains and silk and usually has a long piece of plant stem attached

Figure 17. A leptocerid caddisfly larva (body length = 9.7 mm) and case, *Nectopsyche tavara* (Ross). Ten percent of all caddisflies found in association with hydrilla were *N. tavara*. Larval *Nectopsyche* species are omnivores that feed on detritus, aquatic vascular plants, and small invertebrates. *Nectopsyche tavara* feeds, in part, on hydrilla (Daigle and Haddock 1981)

longitudinally to one side. A *N. tavara* larva and case are shown in Figure 17.

*? 72. *Oecetis* species near *cinerascens* (Hagen) - 95 larvae and pupae in 36 collections from 6 Florida sites, Lake Jackson, Lake Lochloosa, Orange Lake, Rodman Reservoir, SR 841 Canal, and Tamiami Canal (collections 78235, 79268, 79269, 79270, 79272, 79278, 79279, 79285, 79290, 79292, 79302, 79313, 79314, 79317, 79322, 79325, 79394, 79404, 79410, 80203, 80210, 80212, 80214, 80217, 80219, 80223, 80228, 80236, 80249, 80251, 80252, 80256, 80257, 80259, 80263, and 80275). Balciunas (1977, 1982) found a few larvae of this species on waterhyacinth and many larvae on *Myriophyllum spicatum* plants. McGaha (1952) observed *O. cinerscens* feeding on *Myriophyllum heterophyllum* but Wiggins (1977) thought that the larvae of this species are more predaceous than herbivorous. *Oecetis cinerascens* larvae are most likely omnivores that may partially feed on hydrilla. The larval case is composed of silk, leaves, and plant stems. Figure 18 shows a mature larva and case.

*? 73. *Oecetis* species near *inconspicua* - 106 larvae and pupae in 29 collections from 9 Florida sites: Caloosahatchee Tributary, Crystal River Canal, Lake Jackson, Lake Trafford, Orange Lake, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Wacissa River; and Lake Conroe, Texas (collections (Fla.) 78227, 78228, 79270, 79272, 79281, 79292, 79294, 79301, 79311, 79325, 79328, 79334, 79338, 79339, 79349, 79365, 79375, 79402, 79404, 79410, 79411, 80205, 80212, 80219, 80225, 80232, 80245, 80251; and (Tex.) 79379). The larval case is usually composed of sand grains and silk. See *Oecetis* species near *cinerascens* for discussion of feeding habits. A mature larva and case are shown in Figure 19.

Figure 18. A leptocerid caddisfly larva (body length = 7.7 mm) and case, *Oecetis cinerascens* (Hagen). Ninety-five larvae and pupae of this species were found in 36 collections from 6 Florida sites. *Oecetis cinerascens* larvae feed on aquatic vascular plants and detritus. The diet may possibly include hydrilla

Figure 19. A leptocerid caddisfly larva (body length = 10 mm) and case, *Oecetis inconspicua*. Over one hundred larvae and pupae of this species were found in 29 hydrilla collections from 9 Florida sites. *Oecetis* larvae are omnivores which feed in part on aquatic vascular plants. *Oecetis inconspicua* may possibly feed on hydrilla

Figure 20. A leptocerid caddisfly in the genus *Triaenodes*. The body length of this mature larva is 9.6 mm. Only two *Triaenodes* larvae were found in association with hydrilla. Both specimens were from rivers in northern Florida. *Triaenodes* larvae are omnivores which feed partially on aquatic vascular plants, possibly on hydrilla

*? 74. *Triaenodes* species - 2 larvae in 2 collections from the Crystal and Wacissa Rivers, Florida (collections 79263 and 79316). *Triaenodes* larvae are often found in association with aquatic plants (Wiggins 1977). Wiggins also noted that the larvae feed on vascular plants and fine organic particles (detritus?). This species may partially feed on hydrilla. Figure 20 shows a mature *Triaenodes* larva.

- Family PHRYGANEIDAE

75. *Ptilostomis* species - 1 pupa from Rodman Reservoir, Florida (collection 79295). Wiggins (1977) states that the larvae are mostly predaceous.

- Family POLYCENTROPODIDAE

76. *Cyrnellus fraternus* (Banks) - 1 larva from Crystal River, Florida (collection 79274). This species is usually found in large rivers. The larvae feed on invertebrates and fine organic particles (detritus?) (Wiggins 1977). The genus has only one North American species.

77. *Polycentropus* series A - 7 larvae in 4 collections from Lake Jackson and the SR 841 Canal, Florida (collections 78216, 78241, 79272, and 80262). Balciunas (1977) took several *Polycentropus* larvae on water-hyacinth roots. Wiggins (1977) states that the larvae are mostly predaceous.

78. *Polycentropus* species B - 1 larva from Lake Conroe, Texas (collection 79378). This specimen appears to be distinct from those taken in Florida.

- Family RHYACOPHILIDAE

79. *Atopsyche* species - 1 larva from the San Marcos River, Texas (collection 79377). Only 3 or 4 species of *Atopsyche* are known from the United States and all are probably predaceous in the larval stage (Wiggins 1977).

• Family SERIOCOSTOMATIDAE

80. *Agarodes* species - 3 pupae from two collections on the San Marcos River, Texas (collections 79377 and 80272). The pupal cases of these specimens suggest that they are an *Agarodes* species. The larvae probably feed mostly on detritus (Wiggins 1977).

Undetermined TRICHOPTERA—

Eight larvae were collected in 8 collections from 6 Florida sites, Broward Condo Lake, Lake Lochloosa, Rodman Reservoir, SR 841 Canal, Tamiami Canal, Wacissa River; and Lake Livingston, Texas (collections (Fla.) 79268, 79289, 79295, 79352, 79362, 79396, 80201; and (Tex.) 79380). These specimens could not be identified because they were either pupae or immature larvae without cases.

Order Lepidoptera (Moths and Butterflies)

• Family PYRALIDAE (Snout Moths)

Three hundred and eighteen Lepidoptera larvae, pupae, and teneral adults were found in 31 hydrilla collections from 16 Florida sites. Another 23 specimens were from the SR 24 Canal in Louisiana, 10 specimens were from the San Marcos River in Texas, and 9 specimens were from Rio Chagres, Panama. The total 360 Lepidoptera represented 2 percent of all insects collected; 13 percent of the collections contained Lepidoptera; and Lepidoptera were found at 25 percent of the sites sampled.

Approximately 5 genera and 8 species of pyralids were collected. *Parapoynx diminutalis* (Snellen) and *Synclita obliteralis* (Walker) were the most abundant aquatic moths found in association with hydrilla. These species represented 91 percent of all Lepidoptera collected. *Parapoynx diminutalis* was the most frequently encountered aquatic moth. Four species of aquatic pyralids were recorded from hydrilla for the first time. However, of these, only *Parapoynx allionealis* Walker and *Parapoynx obscuralis* (Grote) definitely ate hydrilla while *Oxyelophila callista* (Forbes) was a probable feeder and *Eoparargyractis* species most likely ate algae. Dr. Dale H. Habeck, Department of Entomology, University of Florida, identified most of the specimens.

Of the few Lepidoptera adapted to aquatic habitats, pyralids are generally the most diverse, widespread, and abundant such group. The family Pyralidae is itself largely terrestrial but some species in the subfamilies Schoenobiinae, Crambinae, and Pyraustinae have aquatic or semiaquatic stages. However, most species in the subfamily Nymphulinae are aquatic. Only nymphulines were taken in the present survey. Populations of aquatic Lepidoptera are probably highly limited by predaceous insects and vertebrates such as fish and birds.

The North American Nymphulinae can be subdivided into the tribes Ambiini, Argyractini, and Nymphulini. All life stages of the Ambiini are terrestrial but the Argyractini and Nymphulini consist of species which are aquatic or semiaquatic as immatures and occasionally as adults. Munroe (1972) elaborates on the taxonomy and biology of aquatic pyralids.

• Tribe ARGYRACTINI

In North America, most species in the tribe Argyractini probably feed on algae in the larval stage (Munroe 1972) and have no direct impact on hydrilla. Only a few specimens belonging to this tribe were found in the present survey.

81. *Eoparargyractis* species - 3 larvae in 2 collections from Lake Jackson and the St. Marks River, Florida (collections 80205 and 80221). These specimens may be either *Eoparargyractis irroratalis* (Dyar) or *Eoparargyractis floridalis* Lange, the only species known to occur in Florida. Both Munroe (1972) and Habeck (1975) state that *Eoparargyractis* larvae feed on algae. Balciunas (1982) also took a larva on *Myriophyllum spicatum*. The larvae probably feed on the microflora growing on leaf and stem surfaces.

*? 82. *Oxyelophila callista* (Forbes) - 4 larvae in 3 collections from the San Marcos River, Texas (collections 80269, 80270, and 80271). This species has not been recorded since it was first described in 1922 (Munroe 1972). While the larva of *O. callista* is unknown, Dr. Habeck believes that these specimens are this species based on unique characteristics which separate them from the known genera of aquatic moth larvae and because they were collected in the same area as the type specimens. The feeding habits of *O. callista* are unknown, but they probably, at least occasionally, feed on aquatic macrophytes. Examination of the gut contents of several larvae revealed the presence of some vascular plant tissue. Balciunas (1982) also collected 2 of those larvae on Eurasian watermilfoil. An *O. callista* larva is shown in Figure 21.

Figure 21. The larva (body length = 9 mm) of a rare aquatic moth, *Oxyelophila callista* (Forbes) (Pyralidae: Argyractini). Only a few larvae of *O. callista* were taken on hydrilla in Texas. Most argyractines are algal feeders but examination of the gut contents of several *O. callista* larvae revealed the presence of some vascular plant tissue. *Oxyelophila callista* larvae may therefore feed, at least occasionally, on aquatic macrophytes, possibly on hydrilla

Undetermined ARGYRACTINI—

One larva from Rio Chagres, Panama (collection 80277). Dr. Habeck determined that this specimen belonged to the Argyractini; however, not enough is known about neotropical aquatic pyralids to identify the species.

• Tribe NYMPHULINI

Most of the Lepidoptera found in association with hydrilla in the present survey belong to this tribe. The larvae usually build cases from host plant tissue in which they hide while moving and feeding. The cases may aid in concealing the larvae from predators. The larvae may or may not have gills (Munroe 1972).

Larval Nymphulini eat a variety of aquatic vascular plants (Habeck 1975) and are among the few invertebrate herbivores previously recorded feeding on hydrilla. Host records for individual species in the Nymphulini usually include several plant genera and species. Although some aquatic pyralids such as *Synclita obliteralis* may be general feeders on aquatic plants, others such as *Parapoynx diminutalis* may preferentially eat only a few host plants (Baloch 1976).

* 83. *Parapoynx allionealis allionealis* (Walker) - 5 larvae in 4 collections from Lake Jackson and the Tamiami Canal, Florida (collections 79365, 80210, 80256, and 80261). Habeck (1975) lists 13 different hosts for this species in the genera *Brasenia, Eleocharis, Hydrochloa, Mayaca, Myriophyllum, Nymphaea, Potamogeton, Sagittaria, Salvinia,* and *Utricularia. Parapoynx allionealis* is recorded from *Hydrilla* for the first time. Figure 22 shows a mature *P. allionealis* larva.

Figure 22. A mature larva (length = 12.7 mm) of an aquatic moth, *Parapoynx allionealis* Walker (Pyralidae: Nymphulini). While Lepidoptera were found at 25 percent of the sites sampled, only 2 percent of all insects found in association with hydrilla were moths. Although 13 different host plants have been recorded for *P. allionealis*, hydrilla is a new host record

* 84. *Parapoynx diminutalis* (Snellen) - 179 larvae, pupae, and teneral adults in 18 collections from 12 Florida sites: Caloosahatchee Tributary, Crystal River Canal, Lake Lochloosa, Lake Trafford, Loop Road Canal, Myakka River, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, Tamiami Canal, Tampa Fairground Ponds; and Rio Chagres, Panama (collections (Fla.) 78209, 78227, 78251, 79268, 79348, 79356, 79363, 79366, 79368, 79375, 79383, 79400, 79401, 80202, 80256, 80275; and (Panama) 80277). This species was the most frequently encountered aquatic moth and was taken at 17 percent of the sites sampled. *Parapoynx diminutalis* was also the most abundant aquatic moth taken representing 50 percent of all Lepidoptera collected. This Asiatic species was first discovered in the United States in 1975 (Del Fosse, Perkins, and Steward 1976). In previous literature *P. diminutalis* is usually referred to as *Nymphula diminutalis*. However, *Nymphula* larvae lack gills. Since *N. diminutalis* larvae have prominent gills, it would be more correct to consider them as *Parapoynx* (Figure 23). Balciunas and Habeck (1981) describe the rapid spread of this species in Florida. Baloch (1976) records *P. diminutalis* from *Hydrilla, Nymphaea, Potamogeton, Najas,* and *Vallisneria* in Pakistan. Rao and Sankaran (1974) recorded this species feeding on various aquatic macrophytes including hydrilla in India. Varghese and Singh (1976) also found this moth species feeding on hydrilla in Malaysia. *Hydrilla* appears to be the preferred host plant in Florida. Feeding damage caused by several *P. diminutalis* larvae is shown in Figure 24.

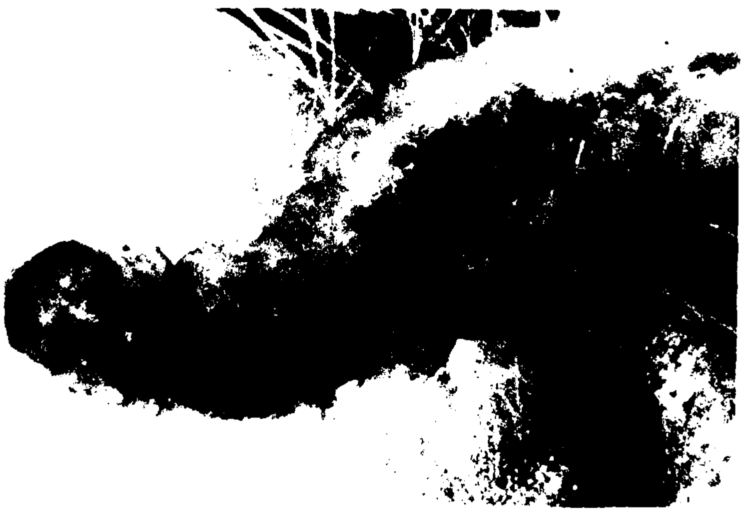


Figure 23. A mature larva (length = 12.4 mm) of an aquatic moth, *Parapoynx diminutalis* (Snellen) (Pyralidae: Nymphulini). This species was the most abundant aquatic moth taken in association with hydrilla, representing 50 percent of all Lepidoptera collected. *Parapoynx diminutalis* is an Asiatic species which has recently become established in Florida. Although this species has been recorded from several plant species in the Old World, hydrilla is the preferred host in Florida

Figure 24. *Parapoynx diminutalis* feeding damage on hydrilla. Note the larval cases constructed from hydrilla leaves

* 85. *Parapoynx obscuralis* (Grote) - 6 larvae in 3 collections from the St. Marks River, Florida, and the San Marcos River, Texas (collections (Fla.) 79385, and (Tex.) 80271 and 80272). Sixteen species of plants in the genera *Ludwigia, Myriophyllum, Najas, Nasturtium, Nuphar, Nymphaea, Nymphoides, Orontium, Polygonum, Potamogeton, Sagittaria, Sparganium,* and *Vallisneria* are listed as hosts of *P. obscuralis* by Habeck (1975). *Parapoynx obscuralis* is recorded from hydrilla for the first time. Balciunas (1982) found this species feeding on Eurasian watermilfoil. Figure 25 shows a mature larva.

Figure 25. A mature larva (length = 11.9 mm) of an aquatic moth, *Parapoynx obscuralis* (Grote) (Pyralidae: Nymphulini). Only a few larvae of *P. obscuralis* were found in hydrilla collections from rivers in northern Florida and Texas. Although 17 different host plants have been recorded for *P. obscuralis*, hydrilla is a new host record

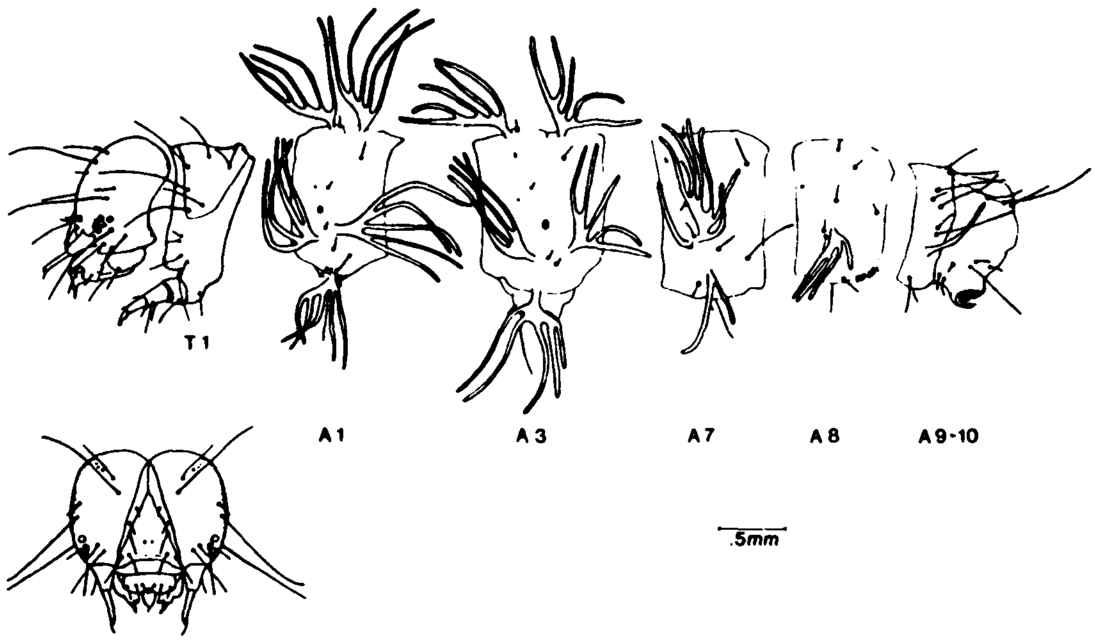


Figure 26. The larva of a Panamanian aquatic moth, *Parapoynx* probably *rugosalis* Moschler (Pyralidae: Nymphulini). This species was commonly found on hydrilla on the Panama Canal in 1980. However, recent expeditions to make further studies of its biology have failed to find any additional specimens

* 86. *Parapoynx* probably *rugosalis* (Moschler) - 3 larvae from Rio Chagres, Panama (collection 80277). Balciunas and Center (1981) studied the host specificity of this species in Panama. Larvae (Figure 26) were found only on hydrilla and *Najas* in the field and these plants were the preferred hosts in the laboratory as well.

Undetermined *Parapoynx* species—

Four larvae, pupae, and teneral adults in 4 collections from 3 Florida sites, Loop Road Canal, St. Marks River, and Tampa Fairground Ponds; and the San Marcos River, Texas (collections (Fla.) 78208, 79385, 80250, and (Tex.) 79377). These specimens were either too immature or damaged for Dr. Habeck to determine them to species.

* 87. *Synclita obliteralis* (Walker) - 150 larvae, pupae, and teneral adults in 6 collections from 4 Florida sites, Lake Lochloosa, Rodman Reservoir, SR 841 Canal, Wacissa River; and the SR 24 Canal in Louisiana (collections (Fla.) 79268, 79355, 79387, 79394, 80275; and (La.) 79381). Although this was the second most abundant aquatic moth collected, the species was present in just 6 collections. Habeck (1975) says that it is the most common nymphuline in Florida. He lists 32 species of host plants in the genera *Azolla, Bacopa, Brasenia, Eichhornia, Egeria, Hydrilla, Hydrocotyle, Lemna, Limnobium, Lindernia, Ludwigia, Myriophyllum, Nelumbo, Nasturium, Nuphar, Nymphaea, Nymphoides, Orontium, Pistia, Polygonum, Pontederia, Potamogeton, Sagittaria, Salvinia,* and *Spirodela.* In combination with *Parapoynx diminutalis,* this species

Figure 27. A mature larva (length = 13.6 mm) of an aquatic moth, *Synclita obliteralis* (Walker) (Pyralidae: Nymphulini). Although *S. obliteralis* was the second most abundant moth found in association with hydrilla, it was taken in only six collections. Some 32 different host plants have been recorded for *S. obliteralis* including hydrilla

has been observed to severely damage hydrilla at Lake Lochloosa, Florida (Balciunas and Habeck 1981). A mature *S. obliteralis* larva is shown in Figure 27.

Undetermined Nymphulini—

Five larvae in 4 collections from Broward Condo Lake and Lake Lochloosa, Florida (collections 79362, 79399, 80201, and 80275). These specimens were too immature to identify even to genus.

Order Coleoptera (Beetles)

A total of 660 larval and adult Coleoptera were found in 68 hydrilla collections from 19 Florida sites. Another specimen was found at the SR 24 Canal in Louisiana and 2 specimens were from the San Marcos River and Lake Livingston, Texas. The 663 Coleoptera represented only 4 percent of all insects collected; 25 percent of the collections contained Coleoptera; and beetles were found at 29 percent of the sites sampled.

Seven families and approximately 23 genera and 29 species of beetles were found in association with hydrilla. Usually only a few specimens of each species were found although *Liodessus flavicollis* (LeConte) was very abundant, representing 87 percent of all Coleoptera collected. This species was also the most frequently encountered beetle but specimens were taken at only 7 different sites. Dr. Charles W. Obrien, Department of Entomology, Florida A&M University, identified the curculionid adults. Dr. Paul J. Spangler, Smithsonian Institution, Department of Entomology, identified most of the other beetle larvae and adults.

Of the beetles collected, at least 90 percent of the specimens and 40 percent of the species are predaceous. Chrysomelids, curculionids, elmids, haliplids, and some hydrophilids are herbivorous (Cummins and Doyen 1978) but many of these

feed on algae or plants other than Hydrochartaceae species (Usinger 1956). Predaceous Coleoptera may associate with hydrilla because the plants shelter prey organisms. Hydrilla may also attract some beetles that feed on algae or detritus because algae and detritus are often associated with this plant. The relatively high number of beetle species and low number of specimens taken in the present survey probably indicate that most Coleoptera were only coincidentally associated with hydrilla. Predaceous beetles may impact hydrilla by reducing populations of herbivorous invertebrates.

- Family CHRYSOMELIDAE (Leaf Beetles)

Chrysomelids are mostly terrestrial beetles but a few taxa such as *Donacia* have aquatic stages.

88. *Donacia* species - 1 larva from Lake Jackson, Florida (collection 79305). Usinger (1956) lists *Myriophyllum, Nuphar, Nymphaea, Potamogeton, Sagittaria,* and *Sparganium* as host plants of *Donacia* species. Both adults and larvae usually feed on the same host species but on different parts of the plants. The larvae are aquatic and feed mostly on submersed portions of the host plant whereas adults usually eat the emergent plant parts. This specimen may have been feeding on hydrilla but more likely was dislodged from some other plant when the sample was taken. Usinger says that some species are often very host specific.

- Family CURCULIONIDAE (Weevils)

The family is mostly terrestrial but a few taxa in a few tribes have aquatic or semiaquatic stages. Both *Brachybamus* and *Stenopelmus* are in the tribe Hydronomini (Arnett 1968). Curculionid larvae usually bore into the host plant. Only 2 species and 5 specimens of curculionids were taken in the present survey.

89. *Brachybamus electus* Germ. - 1 adult from SR 841 Canal, Florida (collection 79349). Dr. Obrien (personal communication) thinks that the larval host of *B. electus* is probably *Carex* but adults can be found on many different semiaquatic plants. *Electus* is the only known species of *Brachybamus.*

90. *Stenopelmus rufinasus* (Gyllenhal) - 2 adults in 2 collections from 2 Florida sites, Crystal River and Wacissa River (collections 79291 and 79369). The host plant is *Azolla* (Obrien, personal communication) but adults are often found on other aquatic plants. This is the only known species in the genus.

Undetermined Curculionidae—

Two larvae from the Wacissa River, Florida (collection 79291). No keys were available to identify aquatic curculionid larvae.

- Family DYTISCIDAE (Predaceous Diving Beetles)

Both adult and larval dytiscids are predaceous, hence their common name. Usinger (1956) lists aquatic insects, crustaceans, leeches, snails, and vertebrates such as tadpoles and small fish among the prey organisms of the larvae. Usinger

also comments that these beetles are more often found in shallow water with aquatic vegetation than in habitats without aquatic plants. Approximately 7 species and 581 specimens of dytiscids were taken in the present survey.

91. *Bidessonotus longovalis* (Blatchley) - 1 adult from Rodman Reservoir, Florida (collection 79394). Balciunas (1977) took a specimen of *B. longovalis* on waterhyacinth roots.

92. *Brachyvatus apicatus* (Clark) - 1 adult from Lake Trafford, Florida (collection 79288). Balciunas (1977) took specimens of *Brachyvatus seminulus* (LeConte) on waterhyacinth roots but not this species.

93. *Cybister fimbriolatus crotchi* (Walker) - 1 larva from the Wacissa River, Florida (collection 79316). Balciunas (1977) also collected a larva of *C. fimbriolatus* on waterhyacinth roots.

94. *Hydroporus clypealis* (Sharp) - adult from the Wacissa River, Florida (collection 78244). Balciunas (1977) found 4 different species of *Hydroporus* on waterhyacinth roots, but not *H. clypealis.*

95. *Hydrovatus* species - 1 larva from Orange Lake, Florida (collection 79343). Balciunas (1977) collected specimens of *Hydrovatus compressus* Sharp, *Hydrovatus inexpectatus* Young, and *Hydrovatus peninsularis* Young on waterhyacinth roots. This larva may be one of these species.

96. *Hygrotus marginipennis* (Blatchley) - 1 adult from Myakka River, Florida (collection 78251).

97. *Liodessus flavicollis* (LeConte) - 575 larvae and adults in 35 collections from 7 Florida sites, Lake Jackson, Lake Lochloosa, Lake Trafford, Orange Lake, Rodman Reservoir, SR 841 Canal, and Tampa Fairground Ponds (collections 78208, 78209, 78210, 78250, 79265, 79268, 79281, 79284, 79288, 79295, 79296, 79301, 79303, 79313, 79314, 79315, 79337, 79343, 79351, 79355, 79363, 79367, 79383, 79399, 79401, 80203, 80214, 80218, 80228, 80240, 80242, 80259, 80263, 80274, and 80275). Only a few specimens of this species were found on *Myriophyllum* by Balciunas (1982) but *L. flavicollis* (Figure 28) was the most abundant and frequently collected beetle associated with hydrilla. *Liodessus flavicollis* was associated with undetermined Libellulidae species ($r = 0.698$, $p = 0.0001$, and $n = 284$) and *Erythemis simplicicollis* ($r = 0.517$, $p = 0.0001$, and $n = 284$).

• Family ELMIDAE (Riffle Beetles)

Larval and adult elmids are herbivorous and are reported to feed on algae, moss, and roots of vascular aquatic plants (Usinger 1956). Cummins and Doyen (1978) list riffle beetles as detrivores or herbivores on algae. These beetles probably do not feed on hydrilla but 18 specimens of about 4 species were associated with this plant.

98. *Dubiraphia dietrichi* (Musgrave) - 1 adult from the Crystal River Canal, Florida (collection 79307).

Figure 28. An adult aquatic beetle (length = 1.7 mm), *Liodessus flavicollis* (Coleoptera: Dytiscidae). Although beetles were found at 29 percent of the sites sampled, only 4 percent of all insects found in association with hydrilla were beetles. *Liodessus flavicollis* was the most abundant beetle taken, representing 87 percent of the 660 Coleoptera collected. Both larvae and adults of *L. flavicollis* are predaceous

99. *Dubiraphia quadrinotata* (Say) - 1 adult from the St. Marks River, Florida (collection 80206). Balciunas (1977) took a few *D. quadrinotata* on waterhyacinth roots.

Undetermined *Dubiraphia* species—

Fourteen larvae in 2 collections from the St. Marks River, Florida (collections 79318 and 80234). These larvae may be either *D. dietrichi* or *D. quadrinotata.*

100. *Phanocerus clavicornis* (Sharp) - 1 larva from the San Marcos River, Texas (collection 80269). This is the only known species in the genus.

101. *Stenelmis* species - 1 larva from the St. Marks River, Florida (collection 79318).

Family HALIPLIDAE (Crawling Water Beetles)

The adults and larvae supposedly feed on vascular plants (Cummins and Doyen 1978) but Usinger (1956) states that filamentous algae are commonly eaten. Haliplids probably do not feed on hydrilla. Only 16 specimens in 4 species of crawling water beetles were found on hydrilla.

102. *Haliplus punctatus* (Aube) - 2 adults in 2 collections from the SR 841 and Tamiami Canals, Florida (collections 79322 and 79347).

103. *Peltodytes floridensis* (Matheson) - 6 adults in 5 collections from 5 Florida sites, Alligator Alley Canal, Loop Road Canal, Myakka River, SR 841 Canal, and Tampa Fairground Ponds (collections 78208, 78225, 78251, 79299, and 79322). Balciunas (1977) took a few specimens of *P. floridensis* on waterhyacinth roots. Usinger (1956) says that adult *Peltodytes* often lay their eggs on aquatic vascular plants such as *Elodea* and *Ceratophyllum* but that the larvae usually feed on filamentous algae.

104. *Peltodytes oppositus* (Roberts) - 2 adults in 2 collections from the Big Bass Lodge Canal and a small stream crossing the Florida Turnpike at 155 mile marker (collections 78221 and 79344). Balciunas (1977) took a few *P. oppositus* on waterhyacinth roots.

105. *Peltodytes sexmaculatus* (Roberts) - 2 adults from Orange Lake, Florida and the SR 24 Canal in Louisiana (collections (Fla.) 80228 and (La.) 79381).

Undetermined *Peltodytes* species—

Four larvae in 4 collections from 3 Florida sites: Lake Lochloosa, Orange Lake, and Tampa Fairground Ponds (collections 78206, 78209, 79343, and 80242). No keys were available to determine haliplid larvae but these specimens probably belonged to one or more of the *Peltodytes* species listed above.

• Family HYDROPHILIDAE (Water Scavenger Beetles)

Most hydrophilids are aquatic in both the adult and larval stages although a few species are terrestrial. The larvae of many species are predaceous (Usinger 1956) but adults may feed on detritus, algae, and perhaps vascular plants (Cummins and Doyen 1978). Approximately 7 species and 23 specimens of hydrophilids were associated with hydrilla. None of these species are expected to eat hydrilla.

106. *Berosus infuscatus* (LeConte) - 1 adult from Orange Lake, Florida (collection 78218). Balciunas (1977) took *Berosus exiguus* Say on waterhyacinth roots. Usinger (1956) says that *Berosus* species probably feed on algae.

107. *Berosus* species - 1 larva from Lake Livingston, Texas (collection 79380). This larva is probably not *B. infuscatus*. Balciunas (1982) found a few *Berosus* larvae on *Myriophyllum spicatum* plants.

108. *Derallus altus* (LeConte) - 1 adult from the SR 841 Canal, Florida (collection 79322). Balciunas (1977) found a few adult *D. altus* on waterhyacinth roots as well.

109. *Enochrus pygmaeus* complex - 12 adults in 5 collections from 4 Florida sites, Alligator Alley Canal, Big Bass Lodge Canal, Broward Condo Lake, and Lake Hicpochee (collections 78221, 78222, 78225, 79345, and 79362).

110. *Enochrus* species A - 1 adult from the SR 841 Canal, Florida (collection

79287). Balciunas (1977) found *Enochrus blatchleyi* (Fall), *Enochrus ochrauus* Melsheimer, and *Enochrus perplexus* (LeConte) on waterhyacinth roots. This specimen may be one of these species.

Undetermined *Enochrus* species—

Three larvae in 2 collections from Alligator Alley Canal and Lake Trafford, Florida (collections 78225 and 78226).

111. *Paracymus* species A - 1 adult from Loop Road Canal, Florida (collection 79299). Balciunas (1977) found a specimen of *Paracymus despectus* (LeConte) on waterhyacinth roots.

112. *Paracymus* species B - 1 adult from the SR 841 Canal, Florida (collection 79300).

113. *Tropisternus* species - 2 larvae from Orange Lake, Florida (collection 78218). Balciunas (1977) also found a few *Tropisternus* larvae on waterhyacinth roots.

- Family NOTERIDAE (Burrowing Water Beetles)

Noterid larvae burrow into soft substrates around the roots of aquatic plants where they probably feed on detritus and small invertebrates. The adults are predaceous (Cummins and Doyen 1978). Only 4 species and 16 specimens of Noterids were found in association with hydrilla.

114. *Hydrocanthus oblongus* (Sharp) - 8 adults in 3 collections from Orange Lake and the SR 841 Canal, Florida (collections 78218, 79311, and 79343). Many specimens of this species were taken by Balciunas (1977) on waterhyacinth roots.

115. *Hydrocanthus regius* (Young) - 5 adults in 4 collections from 3 Florida sites, Loop Road Canal, Orange Lake, and SR 841 Canal (collections 79321, 79331, 79371, and 79398). Many specimens of *H. regius* were taken on waterhyacinth roots by Balciunas (1977).

116. *Suphis inflatus* (Leconte) - 1 adult from Orange Lake, Florida (collection 78218). Balciunas (1977) took many specimens of *S. inflatus* on waterhyacinth roots.

117. *Suphisellus gibbulus* (Aube) - 2 adults from Loop Road Canal, Florida (collection 79348). Many specimens were taken on waterhyacinth roots by Balciunas (1977).

Undetermined Coleoptera—

Three larvae in 3 collections from 3 Florida sites, Lake Lochloosa, Lake Trafford, and Tamiami Canal (collections 79288, 80266, and 80275). These larvae were too badly damaged to identify.

Order Diptera (True Flies)

A total of 9762 larval, pupal, and adult Diptera were found in 174 hydrilla collections from 30 Florida sites. Another 48 specimens were from Lewis Pond in Georgia; 15 specimens in 2 collections were from the SR 24 canal in Louisiana; 1 specimen was found at Lake Gatun, Panama; and 93 specimens were taken in 8

collections from a fish hatchery pond, Lake Conroe, Lake Livingston, and the San Marcos River, Texas. These 9919 Diptera represented 57 percent of all insects collected; 65 percent of the collections contained Diptera; and Diptera were found at 49 percent of the sites sampled. Eight families and approximately 51 genera and 89 species of aquatic Diptera were collected in association with hydrilla. Only 3 dipteran larvae were in such poor condition that they could not be determined to family. Dr. Annelle R. Soponis, Laboratory of Aquatic Entomology, Florida A&M University, identified representative specimens of the chironomid pupae and adults. Dr. William M. Beck of Jacksonville, Fla., and Jerrell Daigle, Department of Environmental Regulation, Tallahassee, Fla., determined representative chironomid larvae.

Most adult dipterans are terrestrial. Adults found in the hydrilla collections were usually teneral and probably emerged from pupae after the samples had been taken, although a few of the specimens may have been resting on the water surface or topped-out hydrilla. Immature stages of aquatic Diptera typically frequent substrates such as bottom sediments, aquatic vegetation, and detritus in lentic and lotic habitats. Larvae of many species feed on detritus, algae, or invertebrates, but filtering fine organic particles and microinvertebrates from the water is also a common feeding adaptation. Some larval Diptera may impact hydrilla by providing entrances for plant pathogens and by direct feeding. A few filter-feeding chironomids frequently excavate burrows in aquatic vegetation and although they may do little direct damage, the burrows can provide access points for pathogenic plant fungi and bacteria. Shore fly (Ephydridae) larvae in the genus *Hydrellia* are herbivorous and feed within the stems and leaves of aquatic vascular plants. *Hydrellia* are herbivorous and feed within the stems and leaves of aquatic vascular plants. *Hydrellia* and some chironomid larvae were occasionally found within hydrilla stems in the present survey.

- Family CERATOPOGONIDAE (Biting Midges)

Three genera, 4 species, and 42 specimens of biting midges were collected in association with hydrilla. Most of the specimens were pupae. Except for the head capsule, the larvae are nearly transparent and may have been largely overlooked. All of the taxa found are predaceous in the larval stage (Cummins et al. 1978). Balciunas (1977) collected a few ceratopogonids on waterhyacinth roots.

118. *Bezzia* species - 9 larvae and pupae in 6 collections from 5 Florida sites, Lake Jackson, NW 25 St. Canal, Orange Lake, Rodman Reservoir, and SW 76 Ave. Canal (collections 78211, 78212, 78228, 79367, 80228, and 80245).

119. *Palpomyia* species - 1 pupa from the Wacissa River, Florida (collection 80255).

120. *Stilobezzia* species A - 29 pupae in 2 collections from Broward Condo Lake and the Wacissa River, Florida (collections 79324 and 79345).

121. *Stilobezzia* species B - 1 pupa from the SR 841 Canal, Florida (collection 79322).

Undetermined *Stilobezzia* species—

One adult from the Wacissa River, Florida (collection 80255).

Undetermined Ceratopogonidae—

One adult from Rodman Reservoir, Florida (collection 79284).

- Family CHAOBORIDAE (Phantom Midges)

122. *Chaoborus* species - 2 larvae in 2 collections from Lake Lochloosa, Florida (collections 79399 and 80217). *Chaoborus* larvae are predaceous and feed mostly on microcrustacea (Cummins et al. 1978). Balciunas (1977) found a few specimens among waterhyacinth roots.

- Family CHIRONOMIDAE (Midges)

Approximately 36 genera, 72 species, and 9808 specimens of chironomids were taken in the present survey. Chironomids represented 98 percent of all Diptera taken. The midges *Glyptotendipes seminole* and *Endochironomus nigricans* (Johannsen) were the most abundant insects taken. These two species represented 42 percent of the chironomids and 24 percent of all insects collected. The most frequently encountered Diptera were the midges *Dicrotendipes modestus* (Say) and *G. seminole* which were both found in 21 percent of the collections. The subfamilies, Tanypodinae, Orthocladiinae, and Chironominae, include the majority of chironomid species (Oliver 1971). Each of these subfamilies is composed of several tribes. Generally the Tanypodinae and Chironominae prefer warmer aquatic habitats than the Orthocladiinae.

The larvae of many chironomids have not yet been associated with the adults. In order to be identified, the larvae of the known species must be mounted on microscopic slides. Only key characters of last instars are used in identification, and many of these characters, such as hairs and gills, are fragile and are therefore not present on every specimen. Twenty-three percent of the chironomids collected during this study could not be identified to genus or species because they were too immature or due to poor specimen condition or mounting.

☐ Subfamily TANYPODINAE

Eight genera, 11 species, and 160 Tanypodinae specimens were associated with hydrilla. Most species were uncommon and were infrequently taken. Forty-seven percent of the Tanypodinae collected were *Ablabesmyia parajanta* Roback. This species was also the most frequently collected midge in this subfamily. Most Tanypodinae larvae are active predators or omnivores (Cummins and Coffman 1978). Oliver (1971) states that larval Tanypodinae frequently feed on algae and detritus and that few species may be completely predaceous. However, Bryce and Hobart (1972) point out some morphological adaptions of larval Tanypodinae for predaceous feeding. Living Tanypodinae larvae vary in color but are often red.

123. *Ablabesmyia mallochi* (Walley) - 2 larvae in 2 collections from Lake Jackson and the SR 839 Canal, Florida (collections 78240 and 80219). *Ablabesmyia* belongs to the tribe Pentaneurini. Beck (1977) lists *A. mallochi* as a predator found on bottom substrates and aquatic plants in lotic and lentic aquatic habitats.

124. *Ablabesmyia ornata* - 1 larva from the NW 25 St. Canal, Florida (collection 78211). This species is a predator or omnivore found on aquatic vegetation in lotic and lentic habitats (Beck 1977).

125. *Ablabesmyia parajanta* Roback - 75 larvae in 24 collections from 11 Florida sites, Broward Condo Lake, Homossasa Springs, Lake Jackson, Lake Lochloosa, Lake Trafford, NW 25 St. Canal, Orange Lake, SR 841 Canal, SW 76 Ave. Canal, Wacissa River, 72 Ave. Canal, and Lake Conroe, Texas (collections (Fla.) 78211, 78212, 78224, 78252, 79268, 79272, 79314, 79323, 79335, 79346, 79350, 79351, 79356, 79362, 79400, 79404, 80213, 80219, 80260, 80262, 80267, 80268, 80275; and (Tex.) 79378). *Ablabesmyia parajanta* was the most abundant and most frequently encountered tanypodine collected. Beck (1977) lists *A. parajanta* as a predator or omnivore. Simpson and Bode (1980) also found this species to be predaceous. *Ablabesmyia parajanta* was associated with *Enallagma species* C ($r = 0.675$, $p = 0.001$, $n = 284$), *Dicrotendipes* species ($r = 0.657$, $p = 0.001$, $n = 284$), *Dicrotendipes leucoselis* ($r = 0.578$, $p = 0.0001$, $n = 284$), and *Oxyethira* species D ($r = 0.557$, $p = 0.0001$, $n = 284$). Figure 29 shows the head capsule of a mature larva.

Figure 29. A midge larva (length = 5 mm) in the subfamily Tanypodinae, *Ablabesmyia parajanta* Roback (Diptera: Chironomidae). Diptera, especially midges, were the most abundant invertebrates found in association with hydrilla, representing 57 percent of all insects collected. True flies were also found at 49 percent of the sites sampled and 65 percent of the 289 collections. However, only 160 specimens in the subfamily Tanypodinae were collected, about half of which were *A. parajanta*. Most Tanypodinae midge larvae are predaceous

126. *Clinotanypus* species - 12 larvae in 3 collections from the Crystal River and Lake Lochloosa, Florida (collections 79274, 80201, and 80275). *Clinotanypus* belong to the tribe Coelotanypodini. Beck (1977) lists this genus as occurring in bottom sediments and on aquatic plants in lotic and lentic habitats. *Clinotanypus* larvae are predaceous.

127. *Coelotanypus concinnus* (Coquillett) - 1 larva from Lake Lochloosa, Florida (collection 80217). *Coelotanypus concinnus* is found on bottom sediments in lotic and lentic aquatic habitats. This species is a predator and a scavenger (Beck 1977).

128. *Coelotanypus tricolor* (Lowe) - 18 larvae in 7 collections from Lake Lochloosa, Florida (collections 79399, 80201, 80217, 80227, 80241, 80252, and 80275). Beck (1977) lists *C. tricolor* an an omnivore occurring on bottom sediments in lotic and lentic aquatic habitats.

Undetermined *Coelotanypus* species—

Twelve larvae in 3 collections from Lake Lochloosa, Florida (collections 79399, 80201, and 80241).

129. *Labrundinia pilosella* (Loew) - 1 larva from the SR 841 Canal, Florida (collection 79375). *Labrundinia* belongs to the tribe Pentaneurini. This species is found on bottom sediments and aquatic plants in lotic and lentic habitats. Beck (1977) lists *L. pilosella* as a herbivore but both Simpson and Bode (1980) and Cummins and Coffman (1978) state that this species is predaceous.

130. *Natarsia baltimoreus* (Macquart) - 1 larva from the SW 76 Ave. Canal, Florida (collection 78212). Balciunas (1982) found a few specimens of this species on *Myriophyllum spicatum*. *Natarsia* belongs to the tribe Macropelopiini. Simpson and Bode (1980) state that *N. baltimoreus* feeds on unicellur algae, microcrustacea, and other invertebrates.

131. *Pentaneura* species - 2 larvae from the SW 76 Ave. Canal, Florida (collection 78212). *Pentaneura* belongs to the tribe Pentaneurini. Beck (1977) lists *P. inconspicua* (Mallock) as a predator. Simpson and Bode (1980) also found a *Pentaneuria* species from New York to be predeous.

132. *Procladius sublettei* Roback - 9 larvae in 6 collections from 5 Florida sites: Crystal River, Lake Jackson, Lake Lochloosa, SR 841 Canal, and St. Marks River (collections 79337, 80207, 80219, 80234, 80262, and 80267). Balciunas (1982) found a few *P. sublettei* larvae on *Myriophyllum spicatum*. The genus belongs to the tribe Macropelopiini. Menzie (1980) also found *P. sublettei* on *M. spicatum* and noted that the larvae are detrivores and predators that occur mostly on bottom sediments under the plants.

133. *Zavrelimyia* species - 1 larva from Broward Condo Lake, Florida (collection 79362). This genus belongs to the tribe Pentaneurini. The larvae are predaceous (Cummins and Coffman 1978).

Undetermined Tanypodinae—

Twenty-five larvae and 1 pupa in 14 collections from 9 Florida sites, Broward Condo Lake, Crystal River, Crystal River Canal, Inglis Reservoir, Lake Jackson, Lake Lochloosa, Rodman Reservoir, SR 841 Canal, and SW 76 Ave. Canal (collections 78212, 78248, 79307, 79319, 79330, 79345, 79362, 79370, 79383, 80201, 80217, 80219, 80240, and 80262). These specimens were either in poor condition or were mounted so that key taxonomic characters could not be seen. Tanypodinae larvae were associated with *Erythemis simplicicollis* ($r = 0.564$, $p = 0.0001$, $n = 284$).

☐ Subfamily ORTHOCLADIINAE

Walshe (1951) mentions that the larvae of some European Orthocladiinae such as *Cricotopus* species are leaf miners on aquatic vascular plants. Cummins and Coffman (1978) list North American *Cricotopus* species as feeding on aquatic vascular plants, detritus, and algae. Additionally, Beck (1977) lists some *Cricotopus* species as predaceous. The *Cricotopus* species found in this survey probably do not feed on hydrilla. Bryce and Hobart (1972) state that Orthocladiinae larvae usually feed on algae. The larvae are usually green in color and occur in well-oxygenated waters.

Only 6 genera, 12 species, and 149 specimens of Orthocladiinae were collected in the present survey. *Cricotopus sylvestris* (Fabricius) was the most abundant and frequently encountered midge in this subfamily, representing 62 percent of all the Orthocladiinae. Other Orthocladiinae associated with hydrilla were generally not abundant and infrequent in occurrence. Most of the following taxa belong to the tribe Orthocladiini.

134. *Cricotopus bicinctus* (Meigen) - 7 larvae and pupae in 5 collections from 4 Florida sites: Crystal River, Crystal River Canal, Rodman Reservoir, and SR 841 Canal (collections 79375, 79405, 79406, 80258, and 80262). Beck (1977) lists *C. bicinctus* as a herbivore found on bottom sediments and aquatic plants in lotic and lentic habitats. Balciunas (1982) and Menzie (1980) both found larvae of this species on *Myriophyllum spicatum*. *Cricotopus bicinctus* larvae probably feed on algae growing on the leaves and stems of aquatic plants.

135. *Cricotopus remus* Sublette - 2 larvae in 2 collections from Rodman Reservoir, Florida (collections 78234 and 80258). Larvae of this species occur in or on bottom sediments and on aquatic vegetation. Beck (1977) lists *C. remus* as a herbivore but the larvae probably eat algae, not vascular plants.

136. *Cricotopus sylvestris* (Fabricius) - 93 larvae and pupae in 12 collections from 5 Florida sites, Broward Condo Lake, Lake Lochloosa, NW 25 St. Canal, Orange Lake, and Rodman Reservoir (collections 78235, 79399, 79400, 80201, 80202, 80217, 80218, 80222, 80239, 80258, 80263, and 80274). Menzie (1980) and Balciunas (1982) took *C. sylvestris* larvae on *Myriophyllum* species. Menzie feels that the larvae feed mostly on

Figure 30. A midge larvae (length = 6.5 mm) in the subfamily Orthocladiinae, *Cricotopus sylvestris* (Fabricius) (Diptera: Chironomidae). Orthocladiinae midges were not abundant and only 149 specimens were found in association with hydrilla. *Cricotopus sylvestris* larvae comprised 62 percent of these specimens. Most larval Orthocladiinae feed on algae and detritus, although a few may feed on aquatic vascular plants and some are predaceous

detritus. Beck (1977) lists *C. sylvestris* as a herbivore-predator occurring on aquatic plants in lentic habitats. *Cricotopus sylvestris* was associated with *Parachironomus abortivus* ($r = 0.650$, $p = 0.0001$, $n = 284$) and *Glyptotendipes* species ($r = 0.559$, $p = 0.0001$, $n = 284$). The head capsule of a mature larva is shown in Figure 30.

137. *Cricotopus tremulus* (Linnaeus) complex - 2 larvae in 2 collections from Lake Lochloosa and Rodman Reservoir, Florida (collections 80217 and 80263). Current larval keys may include more than one species under the name *C. tremulus* (Simpson and Bode 1980); thus, this species is listed as a complex.

138. *Cricotopus trifasciatus* (Meigen) - 1 adult from the SR 841 Canal, Florida (collection 79410).

Undetermined *Cricotopus* species—

Eight larvae in 3 collections from 3 Florida sites, Crystal River, Lake Lochloosa, and Rodman Reservoir (collections 80215, 80217, and 80258).

139. *Eukiefferiella* species - 1 larva from Rodman Reservoir, Florida (collection 80263). Balciunas (1982) took one larva on *Myriophyllum*. Beck (1977) lists a *Eukiefferiella* species as a herbivore occurring on

aquatic vegetation in lotic habitats. Simpson and Bode (1980) found larvae in the *Eukiefferiella discoloripes* group to feed on algae.

140. *Nanocladius crassicornus* Saether - 3 larvae in 2 collections from Lake Jackson and Orange Lake, Florida (collections 79404 and 80218).

141. *Nanocladius distinctus* (Malloch) - 5 larvae and 1 pupa in 2 collections from Lake Jackson and Rodman Reservoir, Florida (collections 79404 and 80253). The larvae of this species are probably omnivores that feed on both plant and animal tissues (Simpson and Bode 1980).

142. *Nanocladius rectinervis* (Kieffer) - 8 larvae in 3 collections from 3 Florida sites, Lake Jackson, Orange Lake, and Rodman Reservoir (collections 79404, 80218, and 80274). Simpson and Bode (1980) state that *N. rectinervis* is probably an omnivore.

Undetermined *Nanocladius* species—

Three larvae in 3 collections from 3 Florida sites, Crystal River, Lake Jackson, and Orange Lake (collections 79404, 80207, and 80218).

143. *Parakiefferiella* species - 1 larva from the SR 841 Canal, Florida (collection 80262).

144. *Psectrocladius* species - 1 larva and 1 pupa in 2 collections from Broward Condo Lake and Lake Jackson, Florida (collections 79404 and 80239).

145. *Thienemanniella* species - 1 larva from Rodman Reservoir, Florida (collection 80263). This genus belongs in the tribe Corynoneurini. Simpson and Bode (1980) found *T. xena* Roback to feed on unicellular algae.

Undetermined Orthocladiinae—

Eleven larvae in 6 collections from 4 Florida sites, Crystal River, Lake Lochloosa, Rodman Reservoir, and SR 841 Canal (collections 79330, 80207, 80217, 80258, 80263, and 80267).

☐ Subfamily CHIRONOMINAE

Twenty-two genera, 47 species, and 7271 Chironominae specimens were collected in association with hydrilla. Seventy-four percent of all chironomids taken belong to the Chironominae. The most abundant and frequently collected species in this subfamily were *G. seminole, E. nigricans,* and *D. modestus.* Bryce and Hobart (1972) state that Chironominae larvae are usually red in life and are often tolerant of low dissolved oxygen levels. Feeding adaptions in the Chironominae are variable but many species are filter feeders. Some filter feeders shelter themselves by excavating burrows in vascular plants (Walshe 1951). Most of the following species belong to the tribe Chironomini.

146. *Chironomus attenuatus* Walker - 17 larvae in 8 collections at 6 Florida sites, Crystal River, Lake Jackson, Lake Lochloosa, Loop Road Canal, Orange Lake, and Salt Springs (collections 78232, 79289, 79354, 79399, 80228, 80232, 80244, and 80250). Balciunas (1977) took larvae of *C.*

attenuatus on waterhyacinth roots. Beck (1977) lists this species as a predator-scavenger found in or on bottom sediments in lentic and lotic aquatic habitats.

147. *Chironomus decorus* Johannsen - 18 larvae in 5 collections at 3 Florida sites, Lake Jackson, Orange Lake, and Rodman Reservoir (collections 79260, 79272, 79303, 79305, and 80240). Menzie (1980) collected *C. decorus* on *Myriophyllum* but thought the species was mostly a bottom dweller that probably feeds on detritus.

148. *Chironomus riparius* (Meigen) - 8 larvae in 4 collections at 3 Florida sites, Broward Condo Lake, Lake Jackson, and Loop Road Canal (collections 78245, 79409, 79412, and 80219). This species is a scavenger found in or on bottom sediments in lentic and lotic aquatic habitats (Beck 1977).

Undetermined *Chironomus* species—

Thirty-six larvae in 13 collections at 9 Florida sites, Broward Condo Lake, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, Rodman Reservoir, small stream crossing Turnpike at 155-mile marker, St. Mark's River, and SW 76 Ave. Canal (collections 78212, 79288, 79296, 79305, 79337, 79344, 79385, 79409, 79411, 80213, 80219, 80232, and 80245).

149. *Cladotanytarsus* species - 1 larva from Broward Condo Lake, Florida (collection 79412). *Cladotanytarsus* belongs to the tribe Tanytarsini. The larvae occur on aquatic vegetation in lentic and lotic habitats (Beck 1977) and probably feed on detritus and algae (Cummins and Coffman 1978).

150. *Cryptochironomus fulvus* Johannsen - 2 larvae in 2 collections from Rodman Reservoir and the SR 841 Canal, Florida (collections 80240 and 80262). Balciunas (1982) collected a larva of *C. fulvus* on *Myriophyllum spicatum*. Beck (1977) lists this species as a predator-omnivore found on or in bottom sediments in lotic and lentic aquatic habitats. Simpson and Bode (1980) also found *C. fulvus* to be predaceous.

151. *Dicrotendipes incurvus* (Sublette) - 9 larvae and pupae in 6 collections from 4 Florida sites, Lake Jackson, Lake Lochloosa, Rodman Reservoir, and SW 76 Ave. Canal (collections 78212, 79281, 79295, 79354, 80241, and 80258). This species occurs on bottom sediments in lentic aquatic habitats (Beck 1977) and probably feeds on algae and detritus (Cummins and Coffman 1978).

152. *Dicrotendipes leucoselis* (Townes) - 299 larvae in 10 collections from 6 Florida sites, Crystal River Canal, Lake Jackson, Lake Lochloosa, Loop Road Canal, Orange Lake, and SR 841 Canal (collections 79260, 79268, 79333, 79354, 79388, 79400, 80201, 80216, 80218, and 80219). Balciunas (1977) took a larva of *D. leucoselis* on waterhyacinth roots. This species occurs on bottom sediments in lentic and lotic aquatic

habitats (Beck 1977). *Dicrotendipes leucoselis* was associated with *Enallagma* species C ($r = 0.776$, $p = 0.0001$, $n = 284$) and *Ablabesmyia parajanta* ($r = 0.578$, $p = 0.0001$, $n = 284$).

153. *Dicrotendipes modestus* (Say) - 445 larvae and pupae in 62 collections from 17 Florida sites, Broward Condo Lake, Caloosahatchee Tributary, Crystal River, Crystal River Canal, Homossasa Springs, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Tamiami Canal, and Wacissa River (collections 78211, 78212, 78216, 78227, 78228, 78234, 79260, 79264, 79267, 79268, 79272, 79286, 79299, 79301, 79305, 79317, 79321, 79325, 79328, 79333, 79337, 79348, 79350, 79356, 79368, 79373, 79399, 79400, 79404, 79412, 80201, 80202, 80203, 80205, 80208, 80209, 80213, 80214, 80217, 80218, 80219, 80221, 80226, 80232, 80234, 80239, 80240, 80241, 80242, 80244, 80249, 80250, 80252, 80253, 80254, 80258, 80259, 80260, 80263, 80266, 80274, and 80293). Beck (1977) lists this species as an omnivore which occurs on bottom sediments in lentic and lotic aquatic habitats. Menzie (1980) collected *D. modestus* on *Myriophyllum* but considered the larvae to be detrivores. *Dicrotendipes modestus* was associated with *Oxyethira* species D ($r = 0.695$, $p = 0.0001$, $n = 284$) and *Enallagma* species C ($r = 0.539$, $p = 0.0001$, $n = 284$). Figure 31 shows the head capsule of a mature larva.

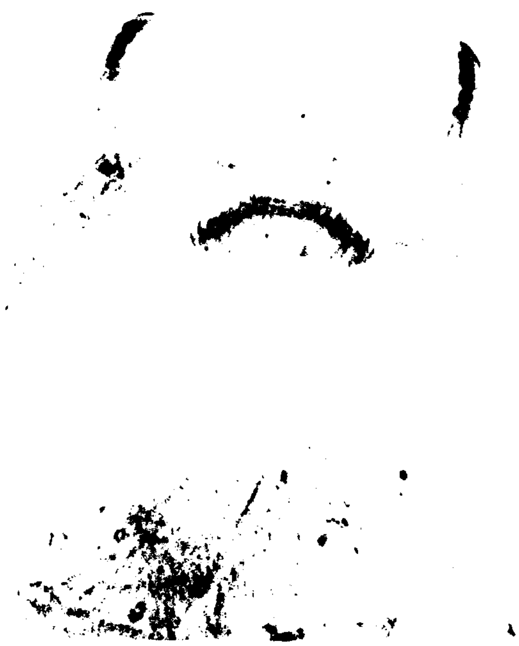


Figure 31. A midge larva (length = 7.2 mm) in the subfamily Chironominae, *Dicrotendipes modestus* (Say) (Diptera: Chironomidae). Several midges in this subfamily, including *D. modestus*, were among the most abundant insects found in association with hydrilla. The larvae of *D. modestus* are omnivores that feed mostly on detritus and algae

154. *Dicrotendipes neomodestus* (Malloch) - 5 larvae in 3 collections from Lake Jackson and Rodman Reservoir, Florida (collections 78234, 79404, and 80258). Balciunas (1982) took many larvae of *D. neomodestus* on *Myriophyllum spicatum* plants. This species occurs in bottom sediments in lotic aquatic habitats (Beck 1977). Simpson and Bode (1980) often found high numbers of *D. neomodestus* larvae together with those of *G. lobiferus* and *D. nervosus*.

155. *Dicrotendipes nervosus* (Staeger) - 26 larvae in 6 collections from 4 Florida sites, Lake Jackson, Orange Lake, Rodman Reservoir, Wacissa River; Lake Livingston, Texas; and Lake Gatun, Panama (collections (Fla.) 79352, 79404, 80202, 80258; (Tex.) 79380; and (Panama) 80273). Beck (1977) lists *D. nervosus* as an omnivore which occurs on and in bottom sediments in lotic and lentic aquatic habitats. Balciunas (1982) took a few larvae of this species on *Myriophyllum spicatum*. Simpson and Bode (1980) often found high numbers of *D. nervosus* larvae together with those of *G. lobiferus* and *D. neomodestus*.

Undetermined *Dicrotendipes* species—

A total of 113 larvae and pupae in 19 collections from 12 Florida sites, Caloosahatchee Tributary, Crystal River Canal, Lake Jackson, Lake Trafford, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, Salt Springs Canal, SW 76 Ave. Canal, Tamiami Canal, and Wacissa River (collections 78211, 78227, 78228, 78232, 79332, 79333, 79335, 79342, 79354, 79404, 80205, 80209, 80218, 80219, 80254, 80258, 80260, 80263, and 80266). These *Dicrotendipes* larvae were associated with *Enallagma* species C ($r = 0.874$, $p = 0.001$, $n = 284$) and *Oxyethira* species D ($r = 0.559$, $p = 0.0001$, $n = 284$).

156. *Einfeldia* species - 2 larvae from 2 collections at Lake Trafford and SW 76 Ave. Canal, Florida (collections 78212 and 79301). Two species of *Einfeldia* are listed by Beck (1977) as scavengers. Cummins and Coffman (1978) also consider the larvae to feed on detritus.

*? 157. *Endochironomus nigricans* (Johannsen) - 1483 larvae in 21 collections at 6 Florida sites, Lake Jackson, Lake Lochloosa, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal; Lewis Pond, Georgia; and Lake Conroe, Texas: (collections (Fla.) 79268, 79269, 79289, 79292, 79296, 79314, 79330, 79337, 79355, 80201, 80205, 80217, 80219, 80222, 80241, 80252, 80258, 80259, 80257; (Ga.) 79390; and (Tex.) 79378). *Endochironomus nigricans* was one of the most abundant and frequently collected dipterans associated with hydrilla. Balciunas (1977, 1982) only took a few specimens on waterhyacinth roots and Eurasian watermilfoil. Beck (1977) lists *E. nigricans* (Figure 32) as a herbivore occurring in and on bottom sediments and aquatic plants in lotic and lentic habitats. *Endochironomus* species are filter feeders which may occasionally excavate burrows in aquatic vascular plants (Walshe 1951).

Figure 32. A midge larva (length = 5.8 mm) in the subfamily Chironominae, *Endochironomus nigricans* (Johannsen) (Diptera: Chironomidae). This species comprised nearly 15 percent of the 9919 Chironomids taken on hydrilla but it was found at only 8 different sites. The larvae of *Endochironomus* species are filter feeders that often excavate burrows in aquatic vascular plants in which to hide. The burrows can provide entrances for pathogenic plant fungi and bacteria

*? 158. *Endochironomus subtendens* (Townes) - 99 larvae in 9 collections at Lake Lochloosa and Rodman Reservoir, Florida, and Lake Conroe, Texas (collections (Fla.) 79330, 79337, 79355, 80227, 80241, 80258, 80259, 80275; and (Tex.) 79378). Balciunas (1982) collected many larvae of *E. subtendens* on *Myriophyllum spicatum*.

*? 159. *Endochironomus tendens* (Fabricius) - 6 larvae in 4 collections from Lake Lochloosa and Rodman Reservoir, Florida (collections 79302, 79337, 80258, and 80263).

Undetermined *Endochironomus* species—

Fifty-eight larvae in 8 collections from 3 Florida sites, Lake Lochloosa, NW 25 St. Canal, Rodman Reservoir; and Lake Conroe, Texas (collections (Fla.) 78211, 79330, 79337, 79355, 80258, 80259, 80275; and (Tex.) 79378).

*? 160. *Glyptotendipes lobiferus* (Say) - 220 larvae in 27 collections from 5 Florida sites, Lake Jackson, Lake Lochloosa, Orange Lake, Rodman Reservoir, SR 841 Canal; and Lake Conroe and Lake Livingston, Texas (collections (Fla.) 78206, 79257, 79268, 79269, 79270, 79278, 79287, 79292, 79296, 79302, 79313, 79337, 79399, 79404, 80203, 80217, 80227, 80240, 80241, 80242, 80245, 80252, 80258, 80259, 80275; and (Tex.) 79379, 79380). Beck (1977) lists *G. lobiferus* as a scavenger occurring in and on bottom sediments and aquatic plants in lotic and lentic habitats. This species is a filter feeder that occasionally excavates burrows in aquatic vascular plants (Leathers 1922). Balciunas (1977, 1982) collected a larva on waterhyacinth roots and many larvae on *Myriophyllum spicatum* plants. Simpson and Bode (1980) often found high numbers of *G. lobiferus* larvae together with those of *D. neomodestus* and *D. nervosus*.

*? 161. *Glyptotendipes paripes* (Edwards) - 64 larvae in 18 collections from 3 Florida sites, Lake Lochloosa, Orange Lake, Rodman Reservoir; Lewis Pond, Georgia; and Lake Conroe, Texas (collections (Fla.) 78235, 79269, 79296, 79302, 79313, 79337, 79399, 79401, 80201, 80217, 80228, 80252, 80253, 80258, 80259, 80275; (Ga.) 79390; and (Tex.) 79379). *Glyptotendipes paripes* is a scavenger occurring in and on bottom sediments in lentic aquatic habitats (Beck 1977).

*? 162. *Glyptotendipes seminole* - 2641 larvae in 61 collections from 10 Florida sites, Crystal River Canal, Lake Hicpochee, Lake Jackson, Lake Lochloosa, Lake Trafford, Orange Lake, Rodman Reservoir, SR 841 Canal, Tamiami Canal, 72 Ave. Canal; Lewis Pond, Georgia; and Lake Conroe, Texas (collections (Fla.) 78206, 78218, 78222, 78224, 78226, 78235, 79256, 79257, 79268, 79269, 79270, 79272, 79278, 79281, 79289, 79292, 79296, 79301, 79302, 79303, 79305, 79307, 79309, 79311, 79313, 79314, 79315, 79330, 79337, 79355, 79356, 79388, 79399, 79400, 79401, 79404, 80201, 80202, 80203, 80214, 80217, 80218, 80219, 80227, 80228, 80229, 80240, 80241, 80242, 80252, 80253, 80258, 80259, 80263, 80264, 80268, 80269, 80275; (Ga.) 79390; and (Tex.) 79379). *Glyptotendipes seminole* (Figure 33) was the most abundant insect associated with hydrilla. This species accounted for 15 percent of all insects taken. *Glyptotendipes seminole* is probably a filter feeder that may occasionally excavate burrows in aquatic vascular plants.

*? 163. *Glyptotendipes senilis* Johannsen - 13 larvae in 5 collections from 4 Florida sites, Lake Hicpochee, Lake Lochloosa, Orange Lake, and Rodman Reservoir (collections 78222, 79270, 79302, 79399, and 80240).

Undetermined *Glyptotendipes* species—

A total of 562 larvae, pupae, and adults in 42 collections from 7 Florida sites, Broward Condo Lake, Lake Jackson, Lake Lochloosa, Orange Lake, Rodman Reservoir, SR 841 Canal, Wacissa River, Lake Conroe, Lake Livingston, and San Marcos River, Texas; and Lewis Pond, Georgia (collections (Fla.) 78235, 79257, 79268, 79269, 79270, 79278,

Figure 33. A midge larva (length = 6.2 mm) in the subfamily Chironominae, *Glyptotendipes seminole* (Diptera: Chironomidae). *Glyptotendipes seminole* was the most abundant insect associated with hydrilla comprising 15 percent of all insects collected. The larvae of *Glyptotendipes* species are filter feeders that often excavate burrows in aquatic vascular plants in which to hide. Such burrows can provide entrances for pathogenic plant fungi and bacteria

79279, 79281, 79289, 79290, 79296, 79302, 79313, 79337, 79343, 79356, 79399, 79400, 79401, 80201, 80217, 80218, 89219, 80227, 80239, 80240, 80241, 80242, 80252, 80253, 80254, 80258, 80259, 80262, 80263, 80264, 80268, 80275; (Ga.) 79390; (Tex.) 79379, 79380, and 80269).

164. *Goeldichironomus* species - 8 larvae in 5 collections from 3 Florida sites, Broward Condo Lake, Lake Lochloosa, NW 25 St. Canal; and the SR 24 Canal, Louisiana (collections (Fla.) 79395, 79412, 80252, 80259; and (La.) 78242). Beck (1977) lists *G. holoparsinus* (Goeldi) as a predator or scavenger. Balciunas (1977) found several *G. holoprasinus* larvae on waterhyacinth roots.

165. *Harnischia* species - 1 larva from the SW 76 Ave. Canal, Florida (collection 78212). Beck (1977) lists 2 species of *Harnischia* as herbivores and 1 as a scavenger. The larvae of *Harnischia* species probably feed on algae and detritus (Cummins and Coffman 1978). McGaha (1952) collected 2 species of *Harnischia* on *Myriophyllum exalbescens* and Balciunas (1977) took a few on waterhyacinth roots.

166. *Kiefferulus* species - 12 larvae in 6 collections from 3 Florida sites: Alligator Alley Canal, Lake Lochloosa, and Rodman Reservoir (collections 79225, 79269, 79296, 79399, 80241, and 80259). *Kiefferulus dux* (Johannsen) is listed by Beck (1977) as a scavenger.

167. *Micropsectra* species - 10 larvae in 4 collections at 4 Florida sites, Crystal River, NW 25 St. Canal, Rodman Reservoir, and Wacissa River (collections 80222, 80240, 80244, and 80260). *Micropsectra* belongs to the tribe Tanytarsiinae. Beck (1977) lists a *Micropsectra* species as a scavenger occurring in and on bottom sediments in lotic aquatic habitats.

168. *Microtendipes caelum* Townes - 22 larvae in 7 collections at 7 Florida sites, Big Bass Lodge Canal, Broward Condo Lake, Lake Jackson, Lake Trafford, NW 25 St. Canal, SR 841 Canal, and Wacissa River (collections 78221, 79335, 79352, 79362, 80219, 80222, and 80262).

Undetermined *Microtendipes* series—

A total of 284 larvae in 27 collections at 11 Florida sites, Broward Condo Lake, Crystal River Canal, Holiday Park Canal, Inglis Reservoir, NW 25 St. Canal, Rodman Reservoir, SR 837 Canal, SR 839 Canal, SR 841 Canal, Tamiami Canal, Wacissa River; and Lewis Pond, Georgia (collections (Fla.) 78211, 78215, 78216, 78217, 78231, 78240, 78241, 79264, 79268, 79315, 79324, 79362, 79375, 79405, 79412, 80208, 80209, 80213, 80216, 80222, 80226, 80243, 80260, 80262, 80266, 80267; and (Ga.) 79390). *Microtendipes* larvae are filter feeders (Cummins and Coffman 1978).

169. *Nilothauma babiyi* (Rempel) - 7 larvae in 5 collections from 3 Florida sites, Crystal River Canal, Lake Jackson, and Rodman Reservoir (collections 78234, 79325, 79328, 80219, and 80263).

170. *Nilothauma bicornis* - 2 larvae in 2 collections from Rodman Reservoir and the SR 841 Canal, Florida (collections 80262 and 80263).

171. *Pagastiella* species - 2 pupae in 2 collections from Broward Condo Lake and the SR 841 Canal, Florida (collections 80212 and 80213). Beck (1977) lists *Pagastiella orophila* (Edwards) as a scavenger.

172. *Parachironomus abortivus* (Malloch) - 28 larvae in 13 collections from 6 Florida sites, Alligator Alley Canal, Broward Condo Lake, Lake Lochloosa, Rodman Reservoir, SR 841 Canal, and 72 Ave. Canal (collections 78224, 78225, 79296, 79301, 79337, 79355, 80213, 80217, 80227, 80241, 80252, 80258, and 80262). Cummins and Coffman (1978) state that *Parachironomus* larvae feed on deritus, algae, and invertebrates. Balciunas (1982) collected a specimen of this species on *Myriophyllum spicatum*. *Parachironomus abortivus* was associated with *Cricotopus sylvestris* ($r = 0.650$, $p = 0.0001$, $n = 284$) and *Glyptotendipes* species ($r = 0.522$, $p = 0.0001$, $n = 284$).

173. *Parachieonomus alatus* (Beck) - 4 larvae in 2 collections from Lake Lochloosa and the NW 25 St. Canal, Florida (collections 80201 and 80209). Beck (1977) lists *P. alatus* as an omnivore occurring on aquatic plants.

174. *Parachironomus carinatus* (Townes) - 22 larvae in 4 collections from 4 Florida sites, Lake Lochloosa, Loop Road Canal, Orange Lake, and SW 76 Ave. Canal (collections 78212, 79314, 79333, and 80201). *Parachironomus carinatus* is an omnivore that occurs on bottom sediments and aquatic plants in lotic and lentic habitats (Beck 1977).

175. *Parachironomus hirtalatus* (Beck and Beck) - 89 larvae in 18 collections from 8 Florida sites, Broward Condo Lake, Lake Jackson, Lake Lochloosa, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, and Tamiami Canal (collections 78211, 79281, 79333, 79362, 79373, 79407, 80201, 80209, 80217, 80218, 80222, 80223, 80227, 80241, 80249, 80250, 80258, and 80261). Beck (1977) lists *P. hirtalatus* as an omnivore that occurs in lentic and lotic aquatic habitats. Balciunas (1977) took a larva on waterhyacinth roots.

176. *Parachironomus monochromus* (Van der Wulp) - 56 larvae and pupae in 12 collections at 6 Florida sites, Lake Jackson, Lake Lochloosa, Loop Road Canal, NW 25 St. Canal, Rodman Reservoir, and SR 841 Canal (collections 78211, 79268, 79289, 79292, 79302, 79333, 79370, 80217, 80227, 80258, 80259, and 80275). This species is an omnivore that occurs on bottom sediments and aquatic plants in lotic and lentic habitats (Beck 1977). *Parachironomus monochromus* was associated with *Ischnura posita* ($r = 0.548$, $p = 0.0001$, $n = 284$).

177. *Parachironomus richardsoni* - 5 larvae in 3 collections from Lake Lochloosa, Florida (collections 79399, 80201, and 80217).

178. *Parachironomus sublette* - 1 larva from Lake Jackson, Florida (collection 79388).

Undetermined *Parachironomus* species—

Twenty larvae in 11 collections from 6 Florida sites, Crystal River Canal, Lake Lochloosa, Loop Road Canal, NW 25 St. Canal, SR 841 Canal, St. Marks River; and the San Marcos River, Texas (collections (Fla.) 79267, 79289, 79337, 80201, 80208, 80217, 80221, 80222, 80241, 80267; and (Tex.) 80271). These *Parachironomus* larvae were associated with *Endochironomus nigricans* ($r = 0.516$, $p = 0.0001$, $n = 284$) and *Orthotrichia* species ($r = 0.501$, $p = 0.0001$, $n = 284$).

179. *Paratanytarsus species* - 29 larvae and pupae in 13 collections from 7 Florida sites, Caloosahatchee Tributary, Crystal River, Lake Jackson, Lake Lochloosa, Rodman Reservoir, SR 841 Canal, and Suwannee River (collections 78205, 79227, 79272, 79289, 79292, 79375, 79388, 79404, 80203, 80205, 80207, 80240, and 80258). *Paratanytarsus* belongs to the tribe Tanytarsini. Balciunas (1982) collected many *Paratanytarsus* larvae on *Myriophyllum spicatum* plants.

180. *Phaenopsectra dyari* (Townes) - 4 larvae from Lake Lochloosa, Florida (collection 79337). The larvae of *Phaenopsectra* species feed on detritus and algae (Cummins and Coffman 1978).

181. *Phaenopsectra flavipes* (Meigen) - 70 larvae in 9 collections from 5 Florida sites, Lake Jackson, Lake Lochloosa, St. Marks River, Tamiami Canal, and Wacissa River (collections 79272, 79387, 79404, 80205, 80217, 80219, 80221, 80236, and 80260).

Undetermined *Phaenopsectra* species—

Four larvae in 4 collections from 4 Florida sites, Lake Jackson, Lake Lochloosa, St. Marks River, and Wacissa River (collections 79272, 79337, 80221, and 80260). Balciunas (1977, 1982) found a few *Phaenopsectra* larvae on waterhyacinth roots and *Myriophyllum spicatum* plants. Beck (1977) lists *Phaenopsectra* larvae as scavengers that occur on bottom sediments in lotic aquatic habitats.

182. *Polypedilum fallax* (Johannsen) - 3 larvae in 2 collections from the SW 75 Ave. Canal and the 72 Ave. Canal, Florida (collections 78212 and 78224). Balciunas (1977) found a few *P. fallax* larvae on waterhyacinth roots. This species has been reported as a scavenger found in and on bottom sediments and on aquatic plants in lentic and lotic habitats. However, McGaha (1952) notes that the larvae are filter feeders that occasionally excavate burrows in *Nuphar* petioles.

183. *Polypedilum halterale* (Coquillett) - 1 larva from the Wacissa River, Florida (collection 78203).

184. *Polypedilum illinoense* (Malloch) - 96 larvae in 22 collections from 11 Florida sites, Alligator Alley Canal, Broward Condo Lake, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, NW 25 St. Canal, SR 841 Canal, St. Marks River, Wacissa River, 72 Ave. Canal; and Lewis Pond, Georgia (collection (Fla.) 78224, 78225, 78226, 78245, 79260, 79268, 79326, 79333, 79362, 79385, 80217, 80219, 80221, 80222, 80227, 80232, 80250, 80254, 80260, 80262, 80267; and (Ga.) 79390). Beck (1977) lists this species as an omnivore found on bottom sediments and aquatic plants in lotic and lentic habitats. Menzie (1980) found the larvae mostly on *Myriophyllum* plants but thought that they fed on detritus. McGaha (1952) notes that the larvae are filter feeders that occasionally excavate burrows in *Nymphaea* leaves. Balciunas (1977, 1982) took many *P. illinoense* larvae on waterhyacinth roots but only a few on *Myriophyllum spicatum* plants.

185. *Polypedilum scalaenum* (Schrank) - 89 larvae in 14 collections from 13 Florida sites, Alligator Alley Canal, Broward Condo Lake, Caloosahatchee Tributary, Holiday Park Canal, Inglis Reservoir, Lake Lochloosa, Lake Trafford, Salt Springs, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Wacissa River, and 72 Ave. Canal (collections 78224, 78225, 78226, 78227, 78228, 78231, 78232, 78243, 79326, 79337, 79362, 80221, 80238, and 80260). Balciunas (1982) took a few *P. scalaenum* larvae on waterhyacinth roots.

Undetermined *Polypedilum* species—

Forty-two larvae in 5 collections from 5 Florida sites, Alligator Alley Canal, NW 25 St. Canal, SR 841 Canal, St. Marks River, 72 Ave. Canal (collections 78224, 78225, 80221, 80222, and 80267). The larvae of some *Polypedilum* species are herbivores that usually feed on algae but a few are miners in aquatic plants (Cummins and Coffman 1978).

186. *Pseudochironomus richardsoni* (Malloch) - 10 larvae and pupae in 7 collections from 6 Florida sites, Crystal River, Crystal River Canal, Lake Jackson, NW 25 St. Canal, SR 839 Canal, and SR 841 Canal (collections 78240, 78252, 79268, 79405, 79406, 80219, and 80232).

Undetermined *Pseudochironomus* species—

Fifty-three larvae in 22 collections from 11 Florida sites, Broward Condo Lake, Crystal River, Crystal River Canal, Holiday Park Canal, Lake Jackson, Lake Lochloosa, NW 25 St. Canal, Orange Lake, Salt Springs, SR 841 Canal, and SW 76 Ave. Canal (collections 78212, 78228, 78232, 78243, 78252, 79268, 79311, 79328, 79337, 79362, 79375, 79400, 79404, 79406, 79412, 80205, 80207, 80219, 80222, 80232, 80262, and 80267). Cummins and Coffman (1978) list *Pseudochironomus* larvae as collectors-gatherers of detritus and algae. Balciunas (1982) collected a few *Pseudochironomus* larvae on *Myriophyllum spicatum.*

187. *Rheotanytarsus distinctus* - 1 larva from Lake Jackson, Florida (collection 79404). *Rheotanytarsus* belongs to the tribe Tanytarsini. The larvae are filter feeders which construct distinctive cases (Walshe 1951).

188. *Rheotanytarsus exiguus* (Johannsen) - 39 larvae in 8 collections from 5 Florida sites, Caloosahatchee Tributary, Lake Jackson, Lake Lochloosa, Rodman Reservoir, and Wacissa River (collections 78227, 79260, 79404, 80205, 80217, 80219, 80258, and 80260). Beck (1977) lists *R. exiguus* as an omnivore that occurs on aquatic vegetation in lotic and lentic habitats. Balciunas (1982) collected *R. exiguus* from *Myriophyllum spicatum.*

189. *Rheotanytarsus niguus* - 1 larva from Lake Jackson, Florida (collection 79404).

190. *Tanytarsus glabrescens* - 76 larvae in 15 collections from 10 Florida sites, Crystal River, Crystal River Canal, Inglis Reservoir, Lake Jackson, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, SR 841 Canal, and Wacissa River (collections 78231, 79268, 79375, 80208, 80209, 80216, 80218, 80219, 80222, 80244, 80250, 80258, 80260, 80262, and 80267). *Tanytarsus* belongs to the tribe Tanytarsini. Cummins and Coffman (1978) list *Tanytarsus* larvae as collectors, filters, gathers, and scrapers. *Tanytarsus glabrescens* was associated with *Microtendipes* species ($r = 0.556$, $p = 0.0001$, $n = 284$).

191. *Tanytarsus guerlus* - 1 larva from the NW 25 St. Canal, Florida (collection 80209).

Undeterined *Tanytarsus* species—

Fourteen larvae and pupae in 9 collections from 5 Florida sites, Lake Jackson, Lake Lochloosa, NW 25 St. Canal, Orange Lake, and Rodman Reservoir (collections 78211, 79289, 79338, 79404, 80201, 80218, 80222, 80258, and 80263).

192. *Tribelos jucundus* (Walker) - 3 larvae in 3 collections from Lake Lochloosa and the St. Marks River, Florida (collections 79330, 79385, 80259). Beck (1977) lists *T. jucundus* as an omnivore that occurs on bottom sediments in lotic aquatic habitats.

Undetermined Chironominae—

Twelve larvae and 1 adult in 6 collections from 5 Florida sites, NW 25 St. Canal, Rodman Reservoir, SR 841 Canal, SW 76 Ave. Canal, Wacissa River; and the SR 24 Canal, Louisiana (collections (Fla.) 78211, 78212, 78216, 80258, 80260; and (La.) 78242). These specimens were in poor condition and could only be identified to subfamily.

Undetermined Tanytarsini—

Fifteen larvae and 1 adult in 8 collections from 6 Florida sites, Crystal River, Crystal River Canal, Loop Road Canal, NW 25 St. Canal, Rodman Reservoir, and SR 841 Canal (collections 79264, 80203, 80207, 80208, 80222, 80244, 80250, and 80262). These specimens were in poor condition and could only be determined to tribe.

Undetermined Chironomidae—

A total of 2528 larvae and pupae in 121 collections from 21 Florida sites, Alligator Alley Canal, Big Bass Lodge Canal, Broward Condo Lake, Crystal River, Crystal River Canal, Inglis Reservoir, Lake Jackson, Lake Lochloosa, Lake Trafford, Loop Road Canal, NW 25 St. Canal, Orange Lake, Rodman Reservoir, Salt Springs, SR 837 Canal, SR 841 Canal, St. Marks River, SW 76 Ave. Canal, Tamiami Canal, Wacissa River, 72 Ave. Canal; SR 24 Canal in Louisiana; Fish Hatchery Pond, Lake Conroe, and the San Marcos River, Texas (collections (Fla.) 78206, 78211, 78212, 78215, 78218, 78221, 78224, 78225, 78228, 78231, 78232, 78234, 78235, 79255, 79257, 79260, 79268, 79269, 79270, 79272, 79274, 79278, 79279, 79286, 79288, 79289, 79290, 79296, 79298, 79299, 79301, 79302, 79303, 79305, 79311, 79313, 79315, 79319, 79320, 79323, 79324, 79325, 79326, 79327, 79330, 79331, 79332, 79335, 79336, 79337, 79345, 79346, 79351, 79352, 79353, 79354, 79355, 79362, 79367, 79368, 79373, 79375, 79385, 79386, 79395, 79396, 79399, 79400, 79401, 79404, 79405, 79406, 79409, 79410, 79411, 79412, 80202, 80203, 80205, 80207, 80208, 80209, 80213, 80214, 80215, 80216, 80217, 80218, 80219, 80221, 80222, 80225, 80229, 80231, 80232, 80234, 80236, 80240, 80241, 80243, 80244, 80245, 80250, 80252, 80254, 80255, 80258, 80259, 80260, 80262, 80263, 80266, 80267, 80268, 80274, 80275; (La.) 78242; (Tex.) 79376, 79377, 79378, and 79379). These 2528 larvae and pupae represented 23 percent of all chironomids collected in association with hydrilla. The specimens

could not be identified to genus or species because they were early instars or due to poor condition or mounting.

- Family CULICIDAE (Mosquitos)

Most mosquito larvae are filter feeders (Cummins and Newson 1978). Only one pupa was taken in association with hydrilla. Balciunas (1977) collected 5 genera and 6 species of mosquitos from waterhyacinth roots.

193. Undetermined species - 1 pupa from Lake Lochloosa, Florida (collection 80264).

- Family EPHYDRIDAE (Shore and Brine Flies)

* 194. *Hydrellia* species - 50 larvae and pupae in 22 collections from 11 Florida sites, Alligator Alley Canal, Big Bass Lodge Canal, Broward Condo Lake, Crystal River, Crystal River Canal, Lake Jackson, Lake Lochloosa, Orange Lake, Rodman Reservoir, SR 841 Canal, Wacissa River; SR 24 Canal, Louisiana; and Lake Conroe and the San Marcos River, Texas (collections (Fla.) 78221, 78225, 78247, 79268, 79304, 79338, 79362, 79364, 79386, 79404, 79406, 79412, 80214, 80215, 80217, 80228, 80231, 80245; (La.) 79381; (Tex.) 79378, 80270, and 80275). Larvae, pupae, and pupal exuvia of *Hydrellia* species were collected in association with hydrilla. *Hydrellia* larvae are miners in aquatic vascular plants and are commonly found in *Potamogeton* (Deonier 1971). Baloch (1976) found a hydrilla-feeding species of *Hydrellia* in Pakistan. Host specificity tests conducted by Baloch showed that these larvae sometimes feed on *Potamogeton* but prefer hydrilla. Since a few larvae were found in our hydrilla samples, some North American *Hydrellia* species may occasionally utilize hydrilla as a host plant. Also many specimens may have been overlooked because *Hydrellia* larvae are small, inconspicuous, and live within plant tissues. Deonier (personal communication) has found that the mature larvae often pupate on plants other than the larval host. Several species of *Hydrellia* appear to be represented in the hydrilla collections. Figure 34 shows a mature *Hydrellia* larva and a pupa.

- Family PSYCHODIDAE (Moth Flies)

Larval moth flies usually feed on detritus and occur in lentic aquatic habitats (Cummins 1978).

195. *Psychoda* species - 1 adult from Lake Jackson, Florida (collection 79404). This adult was probably resting on the water surface or topped-out hydrilla when the sample was taken.

- Family STRATIOMYIDAE (Soldier Flies)

Stratiomyid larvae are usually found in lentic aquatic habitats and feed on detritus, algae, and occasionally small invertebrates (Usinger 1956). Soldier fly adults are terrestrial.

196. *Odotomyia* species - 11 larvae in 7 collections from 7 Florida sites, Alligator Alley Canal, Caloosahatchee Tributary, Lake Trafford,

Figure 34. A shore fly larva (length = 5.4 mm) and pupa (length = 3.3 mm), *Hydrellia* species (Diptera: Ephydridae). *Hydrellia* larvae are miners in aquatic vascular plants and are commonly found in *Potamogeton* species. Hydrilla is recorded as a North American host plant of *Hydrellia* species for the first time. Only 50 immatures were found in 22 hydrilla collections from sites in Florida, Louisiana, and Texas. These low numbers reflect the difficulty in finding the larvae which spend most of their lives inside hydrilla leaves and stems

Rodman Reservoir, SW 76 Ave. Canal, Wacissa River, and 72 Ave. Canal (collections 78212, 78224, 78225, 78227, 79324, 79351, and 79394). Several species of *Odontomyia* appear to be represented by these specimens. Balciunas (1977) collected many stratiomyid larvae on waterhyacinth roots.

- Family SYRPHIDAE (Flower Flies)

Aquatic syrphid larvae are usually found in lentic aquatic habitats and feed on detritus (Cummins 1978). The larvae breath air directly from the atmosphere through a pair of spiracles located on an extendable tube attached to the posterior end of the body. Thus, the larvae are known as rattailed maggots. Syrphid adults are terrestrial.

197. *Eristalis* species - 1 larva from Lake Lochloosa, Florida (collection 78206). Balciunas (1977) collected a few *Eristalis* larvae from water-hyacinth roots.

Undetermined Diptera—

Three larvae in 2 collections from Lake Lochloosa and the Wacissa River, Florida (collections 80260 and 80264). Only 3 dipteran larvae could not be determined beyond family. These specimens were in very poor condition.

Order Hymenoptera (Bees and Wasps)

Only two specimens of two species of wasps were found in association with hydrilla. The specimens represented two different families, both of which parasitize eggs of other insects. Usinger (1956) lists a few aquatic Hemiptera, Coleoptera, and Odonata as hosts.

- Family MYMARIDAE

  198. *Anagrus* species - 1 adult from the Crystal River, Florida (collection 79413).

- Family TRICHOGRAMMATIDAE

  199. *Prestwichia aquatica* Lubbock - 1 adult from Loop Road Canal, Florida (collection 79299). This specimen appears to be *P. aquatica,* although the identification needs to be verified.

DISCUSSION

Locations and times

This survey was very ambitious in scope, both geographically and temporally. Hydrilla growing in diverse Florida locations and in other states was sampled, with many of the Florida sites being visited on a monthly basis. The great number of locations and the repeated collections at many of these locations provided a good representation of the diversity of habitats in which hydrilla occurs, along with the fauna associated with hydrilla in these diverse habitats. A total of 267 collections from 58 different Florida locations were made. An additional 22 collections from 17 out-of-state locations provided an indication of the geographic variability of the fauna associated with hydrilla.

Characteristics

Inspection of the values listed in Appendix E clearly illustrates the wide range of conditions under which hydrilla will grow. During this survey, hydrilla was collected from water as shallow as 0.1 m, and as deep as 7.6 m, with the average depth for all collections being 1.46 m. The water temperature averaged 22.7°C, with a low of 2°C and a high of 35°C. Conductivity, which is a measure of the dissolved ions present in the water, averaged 417 μmhos, with a low of 20 μmhos at oligothrophic Lake Jackson to a high of 7000 μmhos at the saline Salt Springs. When salinity (salt content) of the water is low, the conductivity is highly correlated with the nutrient content of the water. Most Florida lakes are considered mesotrophic and have conductivity values in the range of 250 to 400 μmhos.

Most hydrilla collection sites had zero salinity. However, hydrilla grew well at Salt Springs, where the salinity was 3.8 ppt. During several brief investigations at Crystal River and Homosassa River, hydrilla was occasionally found growing in water with salinities up to 7 ppt. However, only small clumps of hydrilla (insufficient amounts for a sample) could be found at these higher salinities.

Plant Collection Characteristics

While hydrilla usually formed a dense mat at, or just below, the water surface, at some locations it merely formed a carpet on the bottom. The dry weight averaged slightly more than 8 percent of the wet weight of the samples. The lower leaves on a hydrilla plant are frequently sloughed off, but the data did not show any significant differences in the damage between the upper, middle, or lower leaves or the upper, middle, and bottom portions of the stems.

Insect Species Collected

A total of 59,130 faunal specimens were collected during this survey. Collecting all these specimens required thousands of tedious hours of searching through almost 1500 kg (wet weight) of hydrilla under a microscope. The preservation, identification, and cataloging of all these specimens was also very time-consuming.

Of these specimens, 17,398 (29.4 percent) were insects. Each of the 199 insect species collected was briefly discussed in Part III. Part III also discussed the feeding habits of each of these 199 insect species. True flies (Diptera), with 9,919 specimens, were the most abundant of the insect orders represented and comprised 57 percent of all the insect specimens. Almost 99 percent of these flies were members of the midge (Chironomidae) family. Flies were found in 65 percent of the collections. The larvae and pupae of caddisflies (Trichoptera) were the next most abundant insect order with 4,265 specimens, and these were found in 55 percent of the collections. The larvae of damselflies and dragonflies (Odonata) were the third most abundant order, but with 1,178 specimens, comprised only 7 percent of all the insects collected during this study. The Odonata, especially the damselflies, were, however, well represented with 64 percent of the collections containing at least one Odonata.

The remaining insects (7 additional orders) were not abundant, with no single order comprising more than 4 percent of the insects collected. However, the beetles (Coleoptera), the true bugs (Hemiptera), the mayflies (Ephemeroptera), and the moths (Lepidoptera) were not uncommon in that they were found, respectively, in 25, 33, 34, and 13 percent of the collections. The other three orders (Hymenoptera, Homoptera, and Neuroptera) totaled only 8 specimens among all 3 groups. A detailed summary of the distribution of specimens among the insect taxa is provided in Appendix L.

Species Richness

At least 171 insect species were represented in the 267 collections of hydrilla made during the course of this survey. A comparison with the number of insect species found during similar surveys on other aquatic plant species is of interest. These comparisons are facilitated by constructing a species accumulation curve, i.e. graphing the number of additional "new" species added by each additional collection. A species accumulation curve for all the Florida hydrilla collections is depicted in Figure 35. Balciunas (1977) reported 147 aquatic insect species in a total of 88 collections from waterhyacinth roots. In comparison, after 90 hydrilla

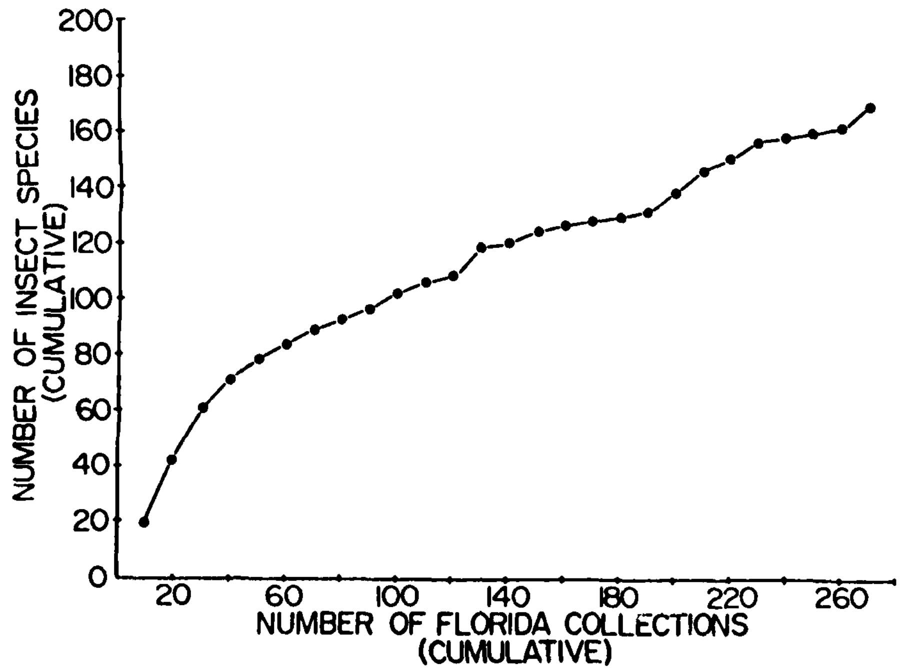


Figure 35. Species accumulation curve for insects collected in association with *Hydrilla verticilla* in Florida. A total of 171 insect species were recorded from hydrilla in Florida. As expected, the first collections added substantially more insect species than did the later collections

collections, only 96 insect species had been recorded. Balciunas (1982) also found a total of 64 insect species in 69 collections of Eurasian watermilfoil. The hydrilla collections yielded over one third more insect species, with 88 species being found after 70 collections.

Thus, hydrilla has a substantially lower richness (number of species) of insects than waterhyacinth root communities. However, hydrilla communities appear to be substantially richer in insect species than a similar submerged plant, Eurasian watermilfoil. The differences in richness of insect species between Eurasian watermilfoil and hydrilla are even greater than the previous comparison suggests. The watermilfoil total of 64 insect species includes those from 48 out-of-state collections. It is usually far easier to record additional species by collecting at new, distant locations, than by repeatedly collecting in the same location. For example, when the 22 out-of-state hydrilla collections were included, an additional 28 insect species were added to the 171 Florida species. Thus, the species richness of insects associated with hydrilla is much greater than that of Eurasian watermilfoil insects.

There are probably at least three reasons why the floating waterhyacinth had a much greater variety of aquatic insects associated with it than did hydrilla. First, waterhyacinth has been in Florida for almost 100 years, while hydrilla has been here less than 25 years, and native insects have therefore had substantially more time to "adapt" to waterhyacinth. Second, the fine structure and close proximity of waterhyacinth roots possibly provides more and better hiding places for insects

and their prey, i.e., waterhyacinth roots allow for "tighter" niche-packing. Thirdly, the water-air interface plays a more important role in waterhyacinth communities, and specialized, surface-film insect species are better represented in waterhyacinth communities.

The reasons for Eurasian watermilfoil's low insect species richness are far from clear. Eurasian watermilfoil has been in the United States for at least 100 years and is relatively common and widely distributed. However, the majority of the sites sampled in the milfoil survey had been infested for less than 20 years, and thus "climax" insect communities were probably not being sampled, which may have resulted in less species being recorded. However, probably none of the hydrilla infestations sampled during the present survey were older than 20 years; therefore, the age of the weed infestations sampled was not the only (or most important) factor determining the number of insect species collected.

Collecting efficiency

Species accumulation curves such as Figure 35 are also useful in studying collecting efficiency and sampling effort. An ideal species accumulation curve is an exponental curve, rising rapidly as the first few collections each add many additional species. After most of the common species are collected, each additional collection would add only a few of the rarer species and the curve would begin to flatten out. Continued collecting would result in only a few, extremely rare species remaining uncollected, and each of these species would only be collected with great effort (i.e., a large number of additional collections). The curve would then become asymptotic at a level corresponding to the total number of species in the community being sampled.

In many ways, the curve in Figure 35 resembles the ideal species accumulation curve. Almost 46 percent of the eventual 171 insect species were recorded in the first 50 collections. The slope of the curve then decreases, i.e. the curve becomes flatter, and the next 50 collections resulted in only an additional 14 percent of the species being added.

However, unlike the ideal species accumulation curve, there is no indication of an asymptote. The curve continues to rise in a linear manner with approximately 35 additional species being added for each additional 100 collections. Thus, additional collecting would almost surely add additional species, although the predicted rate would be around one "new" insect species for every three additional collections.

The lack of an asymptote is not surprising nor even unusual. The ideal species accumulation curve assumes a stable community, where, among other assumptions, no immigration or replacement of species occurs between the first and last collection. This is definitely not the case for hydrilla communities in Florida. Even in mature hydrilla communities, replacement and immigration of species appear to occur regularly. Continued collecting at the same site for several years results in these immigrant species being recorded. Many hydrilla infestations, especially in northern and central Florida, disappear entirely for some months (or years), then reappear with another similar, but not identical community of

associated insects. It is also assumed that a single community is being sampled repetitively. The lumping together of Florida's diverse hydrilla communities into one community almost surely violates this assumption.

Insects Damaging Hydrilla

Many aquatic insects are predatory, feeding on the numerous crustaceans and other small fauna in the water. Of the herbivorous aquatic insects, many feed on dead or decaying plant material. Many of the remaining aquatic insect species feed on algae or diatoms, and seldom damage hydrilla. Thus, relatively few of the insect species collected actually feed on living macrophytes. Hydrilla probably possesses feeding inhibitors which help limit the number of insects that might damage it.

Table 1 presents a list of insect species collected during this study which feed (or are thought to occasionally feed) on living hydrilla. Photographs of representative specimens of each of these species can be found in Part III.

The most numerous and frequently collected of the insects damaging hydrilla were the larvae of five species of caddisflies (Trichoptera), with *Leptocerus americanus* and *Nectopsyche tavara* being the most abundant. *Nectopsyche tavara* is known to feed on hydrilla (Daigle and Haddock 1981) and the other species probably will at least occasionally feed on hydrilla. These species of

Table 1
Insect Species Damaging *Hydrilla verticillata*

Insect Group	*Species Number**	*Scientific Name*	*Number of Specimens*	*Number of Collections*	*Type of Damage To Hydrilla*
HOMOPTERA: Aphids	43	*Rhopalosiphum nymphaeae*	4	2	Hydrilla feeder (sap-sucking on emersed plant parts)
TRICHOPTERA: Caddisflies	70	*Leptocerus americanus*	1593	38	Feeds on leaves of aquatic vascular plants (McGaha 1952)
	71	*Nectopsyche tavara*	440	32	Hydrilla leaf feeder (Haddock and Daigle 1981)
	72	*Oecetis* prob. *cinerascens*	95	36	Aquatic vascular plant feeder (McGaha 1952)
	73	*Oecetis* prob. *inconspicua*	106	29	Probable aquatic vascular plant feeder
	74	*Triaenodes* spp.	2	2	Aquatic vascular plant feeder (Wiggins 1977)
LEPIDOPTERA: Pyralid Moths	82	*Oxyelophila callista*	4	3	Possible hydrilla leaf feeder
	83	*Parapoynx a. allionealis*	5	4	Hydrilla leaf and stem feeder
	84	*Parapoynx diminutalis*	179	18	Hydrilla leaf and stem feeder
	85	*Parapoynx obscuralis*	6	3	Hydrilla leaf and stem feeder
	86	*Parapoynx* prob. *rusosalis*	3	1	Hydrilla leaf and stem feeder
	87	*Synclita obliteralis*	150	6	Hydrilla leaf and stem feeder
DIPTERA: Midges	157-159	*Endochironomus* spp.	**	**	Occasionally burrow into hydrilla stems
	160-163	*Glyptotendipes* spp.	**	**	Occasionally burrow into hydrilla stems
Shoreflies	194	*Hydrellia* spp.	50	22	Hydrilla leaf and stem miners

* See Part III for species number data.
** Although *Endochironomus* and *Glyptotendipes* species were among the most abundant insects associated with hydrilla, these midges were only occasionally found within hydrilla stems.

caddisfly larvae appear to be opportunistic feeders, and do not seem to exhibit any host-specificity in their food preferences.

Of the moth larvae found on hydrilla, six species probably cause damage by feeding on the leaves. Except for *Parapoynx diminutalis* and *Synclita obliteralis,* these moth larvae were relatively rare. *Synclita obliteralis* is known to feed on numerous aquatic macrophyte species both in the field and in the laboratory. In contrast, *P. diminutalis,* while feeding on a broad range of plants in the laboratory, shows a distinct preference for hydrilla in field evaluations. *Parapoynx diminitulis* is the only insect in the United States whose damage to hydrilla, when *P. diminutalis* populations are sufficiently high, will be readily noticeable even to untrained observers. *Parapoynx diminutalis* is an Asiatic species accidentally introduced into the United States. If its range continues to expand and matches that of hydrilla, it will probably play a significant role in the natural control of hydrilla. *Parapoynx rugosalis* is a Panamanian species whose larvae feed on hydrilla. *Parapoynx allionealis* and *P. obscuralis* are also found on hydrilla infrequently, but both of these *Parapoynx* species appear to prefer other aquatic plants as larval hosts.

The ephydrid flies, *Hydrellia* spp., have larvae which mine the leaves and stems of hydrilla. While only 50 immatures of *Hydrellia* were collected during this survey, they are probably much more common. Their tiny size and the necessity of dissecting hydrilla leaves and stems in order to locate the larvae made *Hydrellia* larvae very difficult to locate in a hydrilla sample, even under a microscope.

The sap-sucking aphids, probably *Rhopalosiphum nymphaeae*, were rare on hydrilla, probably since these insects are ill suited for aquatic existence, and could only utilize hydrilla exposed above the water surface, as sometimes occurs in mature mats.

Noticeably absent from this list are any aquatic weevils which feed on hydrilla. Apparently, none of the numerous native United States species of aquatic weevils have yet been able to "switch over" to this newly introduced plant and begin to feed on this now abundant resource. This is additional evidence for the presence of feeding inhibitors in hydrilla tissues.

Snails Associated with Hydrilla

With 28,490 specimens, snails comprised almost half (48.2 percent) of all the fauna collected on hydrilla during this study (Appendix M). A single species, *Goniobasis floridense,* was represented by over 12,000 specimens. The majority of *G. floridense* were found at Wacissa River, where collections routinely contained hundreds, and sometimes in excess of a thousand, snails of this species, and small densities averaged 953 snails/m^2. Other abundant snail species were: *Gryaulus* spp. and *Physa* spp. (each with over 4000 specimens); *Helisoma scalara* (3517 specimens). The first three species in the above list were the most widely distributed species, with each species being found in at least 50 percent of the collections.

Snail densities ranged from 82 to a maximum of 3265 snails/m^2 at Wacissa

River. At most other sites snail densities usually ranged from 50 to 150 snails/m^2 and seldom exceeded 500 snails/m^2.

A total of 25 snail species were recorded on hydrilla during this survey. Most of these snail species were phytophagous. However, their diet appeared to usually consist of algae and other microflora. For example, *G. floridense* appeared to scour the leaf and stem surfaces of hydrilla, apparently feeding on the epiflora. This feeding action did not appear to harm hydrilla. In fact, by increasing the amount of light (previously blocked or utilized by the epiflora) striking photosynthetic tissue, the growth of hydrilla may be increased. The role of hydrilla's epiflora (and of the grazers feeding on the epiflora) remains to be studied.

Other Invertebrates Associated with Hydrilla

Appendix N lists the 11,791 invertebrates, other than insects and snails, collected on hydrilla during this survey. The vast majority—10,892 specimens—were crustaceans. Approximately half of the crustaceans collected (5,341 specimens) were shrimp in the genus *Palaemonetes*. Two species of amphipods, *Hyallela azteca* and *Gammarus* sp A, with 3,522 and 1,440 specimens, respectively, were also common.

Leeches (Hirudinea) were represented by 440 specimens in 6 species. With only 304 specimens, the mites (Acari) were not very abundant, but represented at least 11 species. A small assortment of clams—158 specimens, 5 species—collected with hydrilla roots completes this list.

Vertebrates Associated with Hydrilla

Numerous small fish seek shelter and food in hydrilla mats. Although neither the quantitative samples nor the other collection methods were designed to capture fleeting, mobile fauna such as fish, over 1400 specimens were collected. Larger specimens such as black bass (*Lepomis macrochirus*) and black crappie (*Pomoxis nigromaculatus*) were released immediately, as was a 3-ft eel which had the misfortune of getting "collected" in the sampler. The most common fish species were the bluefish killifish (*Lucania goodei*) with 346 specimens, the least killifish (*Heterandia formosa*) with 338 specimens, and the common mosquito fish (*Gambasia affinis*) with 288 specimens.

A few tree frog tadpoles (*Hyla* spp.) and a single central newt (*Notophthalmus vividescens*) were also collected in hydrilla.

Quantitative Studies

Most collections in Florida were made using the quantitative sampler. However, only six ecologically differing and geographically separated sites will be discussed in detail. All six of these were sampled on a monthly basis, and at least 15 collections were made at each site (except Crystal River, which had only 11 collections due to the loss of the original study site because of continuing herbicidal control activities). A description of the physical and ecological characteristics of each site can be found in Part II.

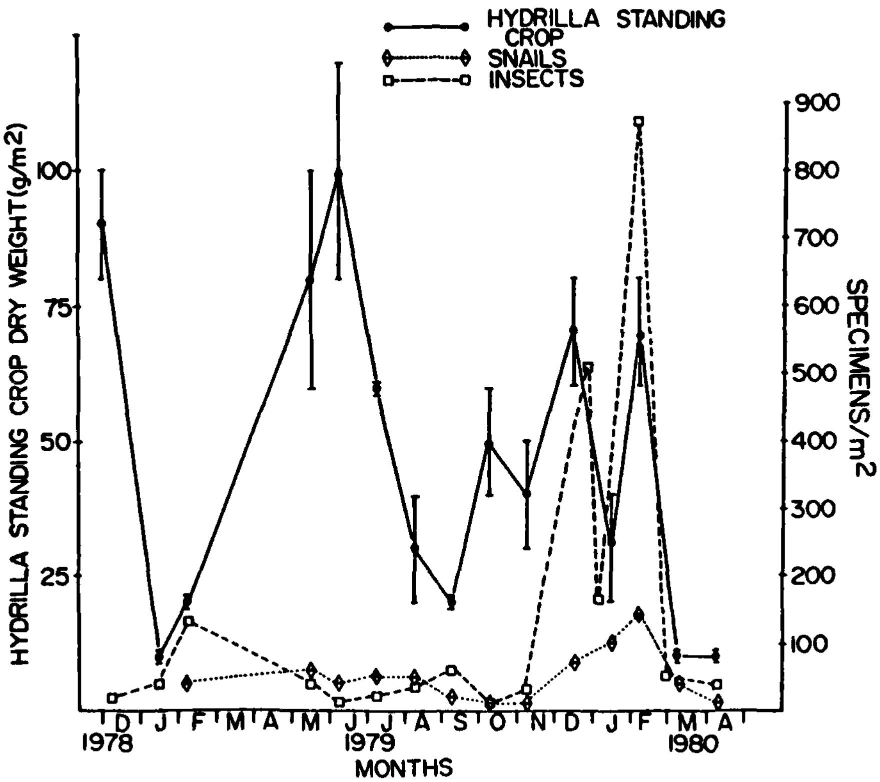


Figure 36. Graph of seasonal changes in the abundance of *Hydrilla verticillata* and associated insects and snails at Lake Jackson, Leon County, Florida. Lake Jackson had the lowest mean standing crop of the six quantitatively sampled study sites

Lake Jackson. Lake Jackson was the northernmost of the six study areas and one of the most unique hydrilla infestations in Florida. There, the standing crop (biomass minus roots) of hydrilla never exceeded 100 g/m^2 (dry weight). This was the lowest standing crop of the six study sites, as might be expected of a location where hydrilla never reached the surface. The cycles of hydrilla (circles), associated insects (squares), and snails (diamonds) are shown in Figure 36. The data for the quantitative collections at Lake Jackson can be found in Appendix F. It is interesting that the peaks in standing crop do not overlap from one year to the next, occurring in mid-summer of 1979 and winter of 1979-80. Peak abundances of insects began to coincide with peak biomass of hydrilla in late 1979 and early 1980 reaching a peak of almost 900 insects/m^2 in February 1980. Snails first appeared in the samples in January of 1979, then remained at low, but constant level of less than 100 snails/m^2, until January and February when they briefly exceeded that level.

The contribution of each of the 16 Lake Jackson collections to the total of 55 insect species collected there is shown in the species accumulation curve in Figure 37. The first 5 collections produced 28 insect species, more than 50 percent of the final total. Subsequent collections usually added only one or two "new" insect species. However, the December 1979 collection produced a sudden increase of 11

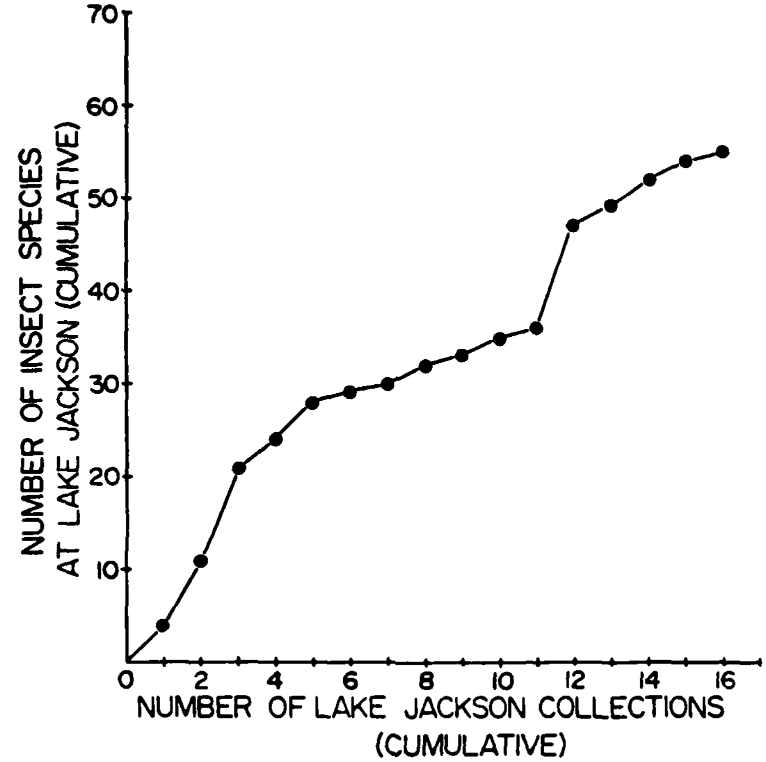


Figure 37. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at Lake Jackson, Leon County, Florida. A total of 55 insect species were recorded from Lake Jackson

additional insect species, 10 of which were midge (Chironomidae) larvae. These midge larvae had probably previously been living on the American lotus (*Nelumbo lutea*) which grew adjacent to, and on top of, the hydrilla being sampled. A hard freeze had killed the *Nelumbo* leaves, and these chironomid larve probably simply dropped off and floated down on the hydrilla, or were feeding on dead *Nelumbo* fragments intermixed with the hydrilla. With 55 insect species, Lake Jackson ranked in the upper half for insect species richness among the six study sites. The overall diversity (Shannon-Weaver) of insect species at Lake Jackson was 2.88, the second highest overall diversity for the six study sites. However, the average diversity index for each collection was 1.88, the highest for all study sites. Thus, while only moderate numbers of insects were collected at Lake Jackson, many insect species were represented, and the specimens were well distributed among the species, i.e., high species evenness.

Wacissa River. This study site in north Florida has a constant, moderate current and is the only river location among the six study sites. Appendix G presents the Wacissa River quantitative data while Figure 38 shows the standing crop and faunal cycles at Wacissa River. The hydrilla biomass at Wacissa River was routinely higher than at any of the other five study sites, dropping to the 100-g/m^2 (dry weight) level only in the winter and exceeding 1000 g/m^2 in June of

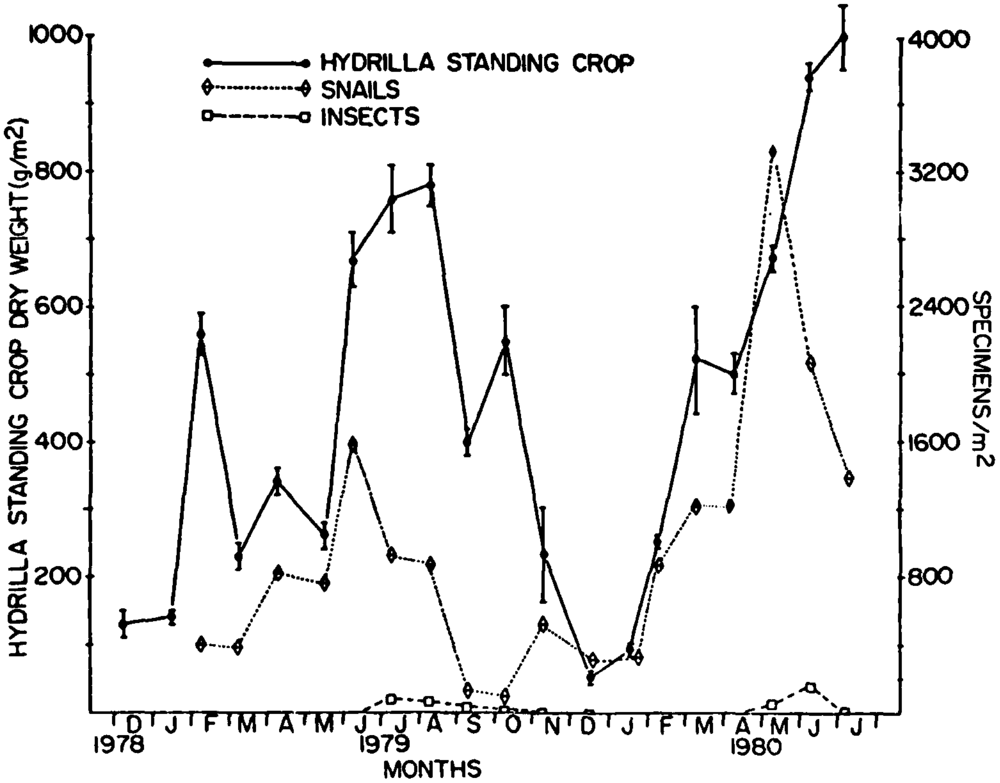


Figure 38. Graph of seasonal changes in the abundance of *Hydrilla verticillata* and associated insects and snails at the Wacissa River, Jefferson County, Florida. This site had the highest mean standing crop and the highest snail industry of the six quantitatively sampled study sites

1980. Biomass of hydrilla at Wacissa River showed a regular cycle peaking in summer with another smaller peak in March. The snail densities at Wacissa River were very, very high and exceeded 3200 snails/m^2 in May of 1980. Approximately 99 percent of these snails were *Goniobasis floridense*. Unlike the snails, insect densities were low, seldom exceeding 100 insects/m^2, and usually about 5 insects/m^2, averaging 21 insects/m^2.

Figure 39 presents the species accumulation curve for the Wacissa River insects. This curve bears little resemblance to the ideal, exponential species accumulation curve. Each of the 20 collections contributed additional insect species in a linear manner. The first 5 collections produced only 8 species while the final 5 collections recorded an additional 11 species. This linear increase is probably due to additional species drifting downstream onto the hydrilla at a slow, but constant rate. With a total of only 37 species, the second lowest of the 6 study sites, Wacissa River's richness of insect species reflected the general paucity of insects at this site. The general scarcity of insects indicates the effect of the moderately strong current. However, the overall diversity of insect species here was a moderate 2.59, as was the average collection diversity of 1.21, indicating an even distribution of specimens among the insect species.

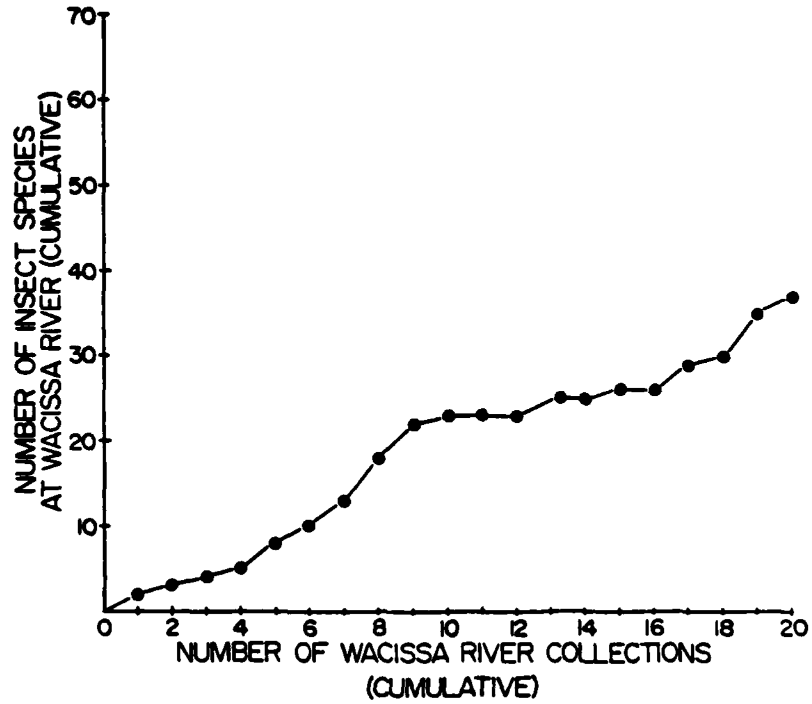


Figure 39. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at the Wacissa River, Jefferson County, Florida. Only 37 insect species were collected at Wacissa River. Each collection, including the early ones, contributed a few additional species to the list

Lake Lochloosa. Appendix H lists the results of the quantitative collections at Lake Lochloosa, a large "swampwater" lake in central Florida. Figure 40 graphically displays these results. The hydrilla standing crop at this site was moderate, usually between 125 and 225 g/m^2 (dry weight), with a dip down to 60 g/m^2 in March and April of 1980. Thus, even during months when hydrilla was not visible from the surface, the standing crop of hydrilla here exceeded the average hydrilla standing crop at Lake Jackson. There is little evidence for a regular cycle in biomass, with the standing crop peaking in October of 1979 and in July of 1980. Insects were very abundant here reaching a high of 3565 insects/m^2 in April 1979 (not shown in Figure 40). However, over 95 percent of the insects were midge (Chironomid) larvae, dominated by a few species such as *Dicrotendipes modestus, Endochironomus nigricans,* and *Glyptotendipes* spp. Snail densities were low to moderate, averaging 82 snails/m^2.

The species accumulation curve for Lake Lochloosa, shown in Figure 41, shows an excellent exponential rise, similar to an idealized species accumulation curve. The first 8 collections contribute an astonishing 46 (85 percent) of the final 54 insect species collected. The curve then abruptly flattens out, and the final 7 collections contribute only 8 additional insect species. In richness of insect species, Lake Lochloosa, with 54 species, ranked around the mode for the 6 study sites. However, the dominance of midges in the collections resulted in an average

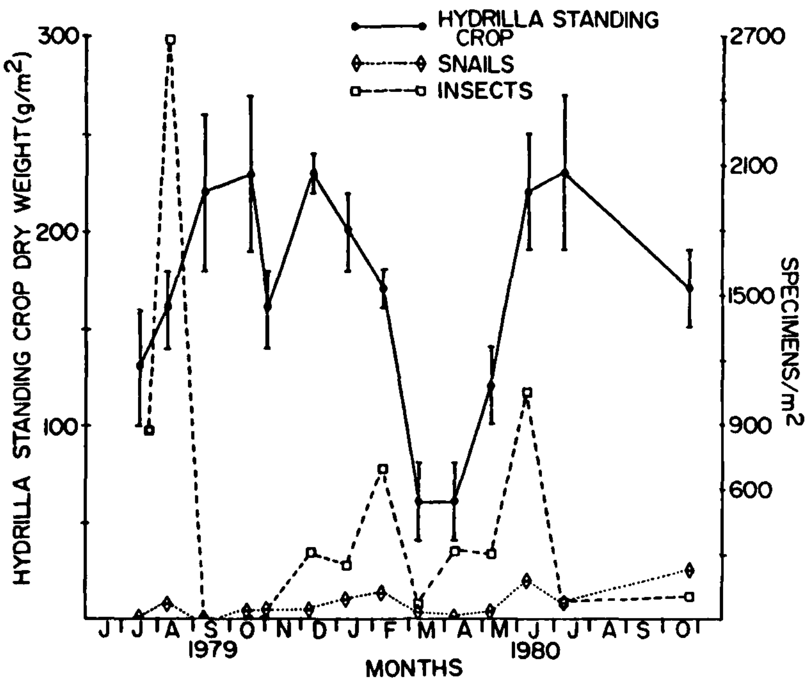


Figure 40. Graph of seasonal changes on the abundance of *Hydrilla verticillata* and associated insects and snails at Lake Lochloosa, Alachua County, Florida. Lake Lochloosa had the highest mean number of insects per square metre of the six quantitatively sampled study sites

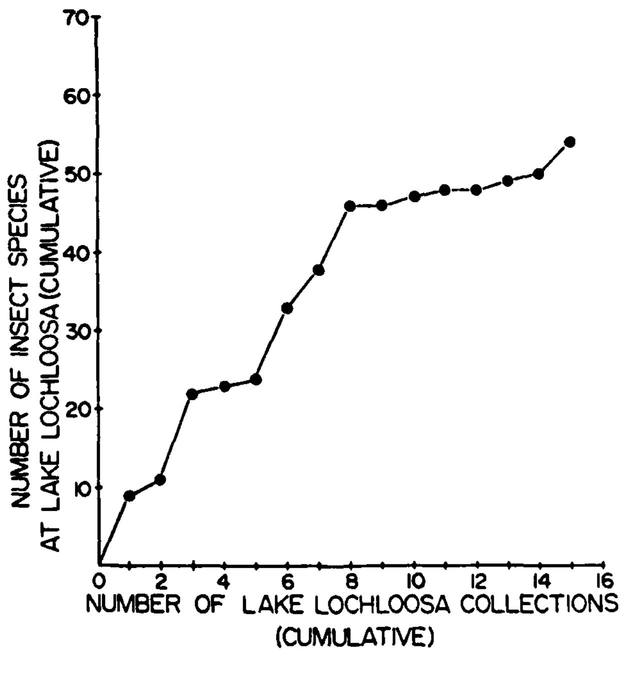


Figure 41. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at Lake Lochloosa, Alachua County, Florida. Similar to the idealized species accumulation curve, most (85 percent) of the insect species had been recorded after just 8 collections

collection diversity of 1.21, the next lowest for all the study areas. The overall diversity for all the specimens collected at Lake Lochloosa was a moderate 1.92.

Rodman Reservoir (Lake Ocklawaha). Lake Ocklawaha, more popularly known as Rodman Reservoir, is a large shallow reservoir in central Florida. The quantitative data for Rodman Reservoir are listed in Appendix I and graphically displayed in Figure 42. Analysis of population cycles at Rodman Reservoir is difficult since the reservoir underwent a drawdown of 1.2 m beginning 30 Aug 1979 and ending 21 Nov 1979 and another 1.2 m drawdown from 11 Jan to 20 Feb 1980. This rapid lowering of the water level destroyed a large portion of the hydrilla in the reservoir. In general, there appears to be a peak in hydrilla biomass in summer and a low in February or March. Insect abundances were sometimes high (1158 insects/m^2 in April of 1980) but fluctuated dramatically. Snail densities were usually low, but reached a level of 474 snails/m^2 in February 1980.

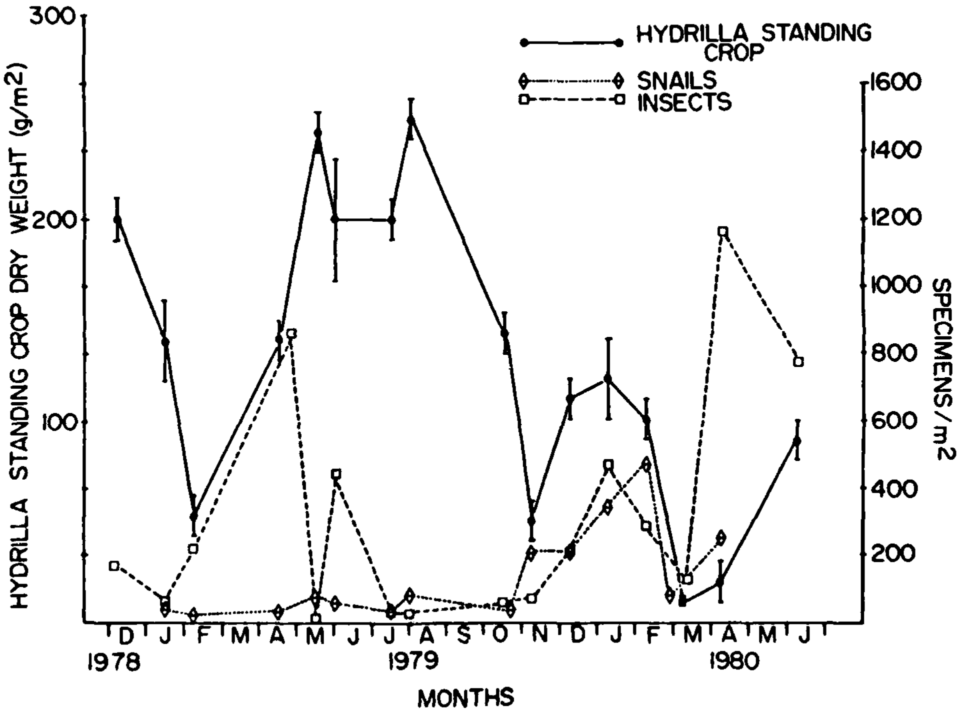


Figure 42. Graph of seasonal changes in the abundance of *Hydrilla verticillata* and associated insects and snails at Rodman Reservoir, Putnam County, Florida. This site had an intermediate abundance of hydrilla, insects, and snails compared with other quantitatively sampled Florida sites

The species accumulation curve for Rodman Reservoir insects, shown in Figure 43, is very unusual. The first 14 collections contributed 34 insect species in a linear manner. However, the final 4 collections added an amazing 25 insect species. Thus, the exponential portion of the curve appears at the end rather than at the beginning as would normally be expected. This is probably because many new insect species appeared after the drawdown to replace the pre-drawdown species.

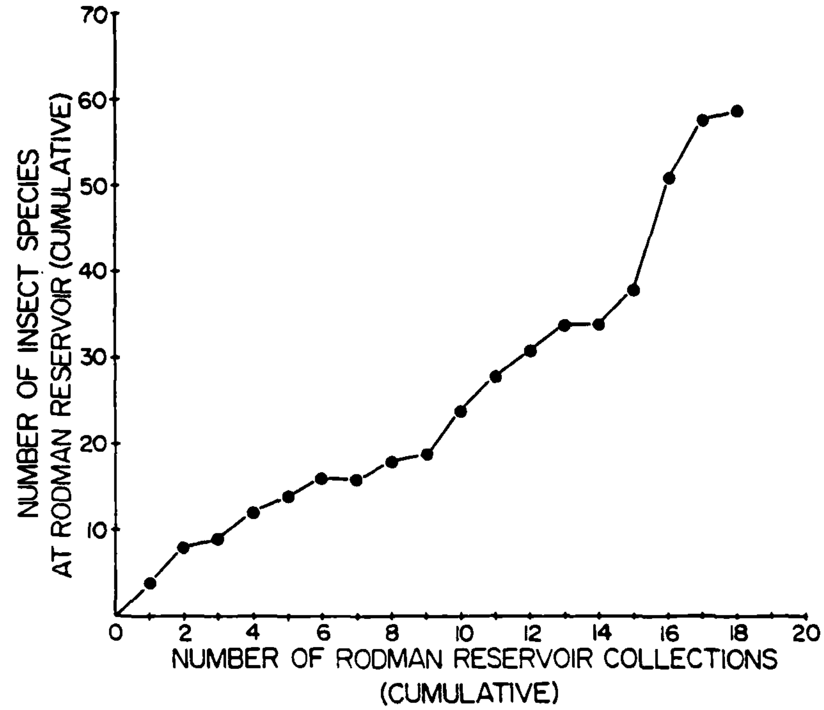


Figure 43. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at Rodman Reservoir, Putnam County, Florida. A total of 59 insect species were collected at Rodman Reservoir. The rapid increase in the number of additional insect species collected at the end of the study period was probably due to new insect species appearing following the fall 1979 drawdown

With 59 insect species, Rodman Reservoir ranked second in insect species richness among the 6 study sites. Both the overall insect diversity (1.86) and the average insect diversity for each (1.29) were in the median range for the 6 study sites, indicating some dominant insect species.

Crystal River. While technically a river, Crystal River was so broad and so close to the Gulf of Mexico that the speed and direction of the current was primarily dependent on the tide. The quantitative data for this site are presented in Appendix J while Figure 44 presents a graphical compilation of these data. The hydrilla standing crop peaked in July at 331 g/m^2. Standing crop minima were reached during the winter (January 1979 and February 1980) when only minute amounts of hydrilla could be collected. Insect density was very low, averaging 33 insects/m^2 and never exceeding 82 insects/m^2. Snail density was also low, averaging 71 snails/m^2 with a maximum of 149 snails/m^2 in December 1980.

The low insect populations consisted of relatively few species with only 21 insect species being recorded from Crystal River. The low number of insect species is an indication of the harsh environment of Crystal River, where only a few species have been able to adapt to the salinity and the constant flux of tidal currents. The species accumulation curve for Crystal River insect species is shown in Figure 45. As at Wacissa River, the curve is essentially linear rather than exponential. The first 5 collections produced 10 species while the last 5

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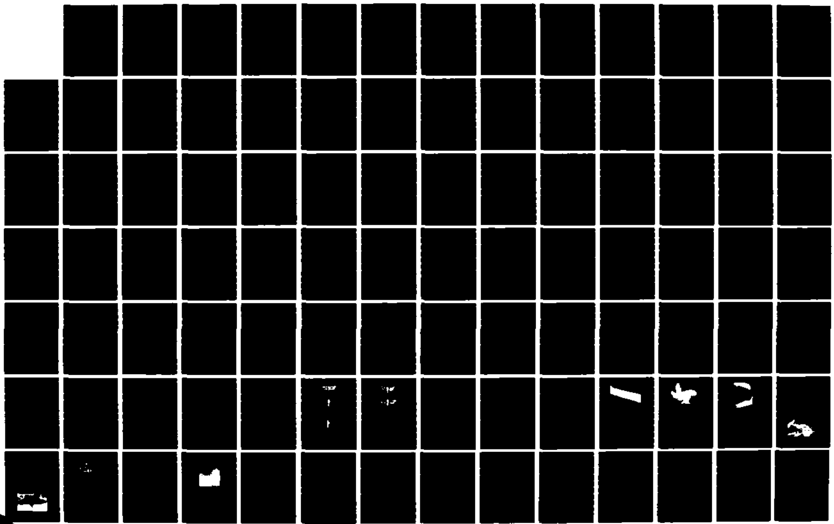

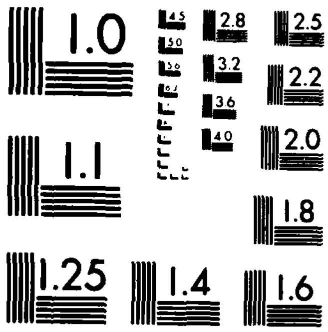

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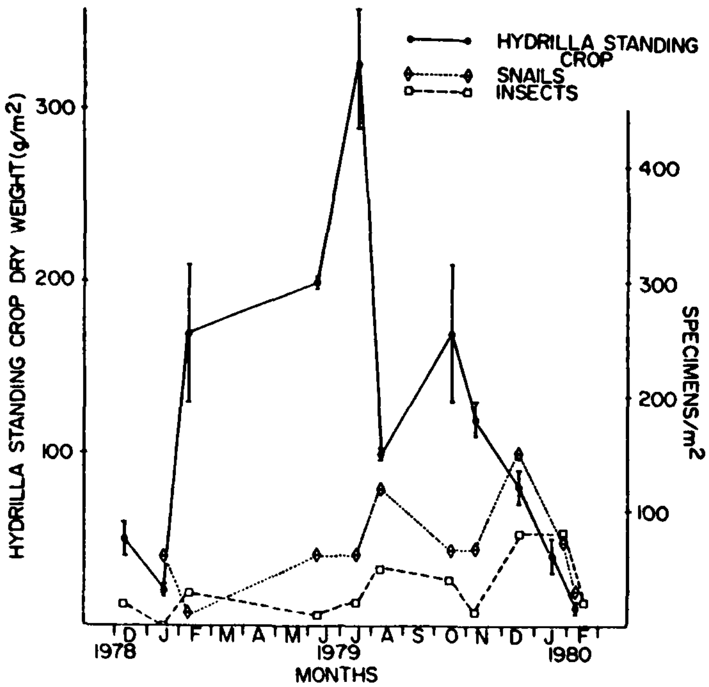

Figure 44. Graph of seasonal changes in the abundance of *Hydrilla verticillata* and associated insects and snails at the Crystal River, Citrus County, Florida. Crystal River had low abundances of hydrilla, insects, and snails compared with other quantitatively sampled Florida sites

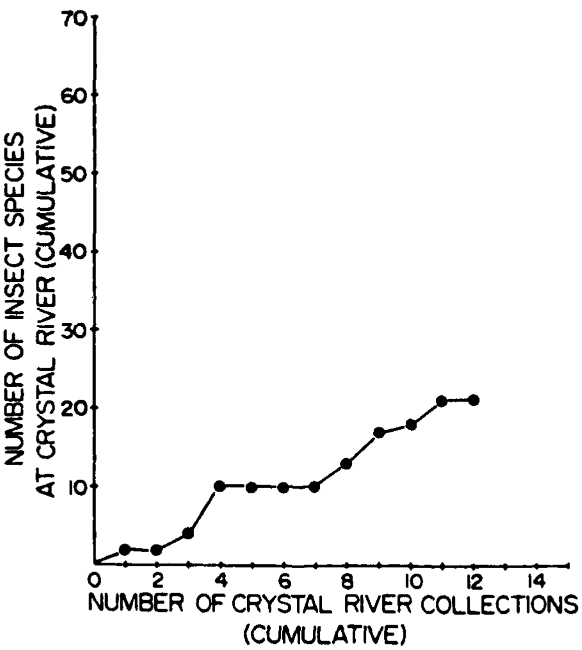

Figure 45. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at the Crystal River, Citrus County, Florida. Only 21 insect species were found at Crystal River, the lowest insect species richness at any of the 6 study sites

collections added 11 insect species. With only 21 insect species, Crystal River had the lowest species richness of the 6 study sites. Not suprisingly, the overall Shannon-Weaver diversity index for all 12 collections was also the lowest (1.82) as was the average diversity index for each collection (1.09). The insect diversity for the collections ranged from a very low 0.095 to a moderate 1.76.

SR 841 Canal. This drainage canal in south Florida was chosen for its remoteness, which helped to ensure that this study site would not be perturbed by weed control activities routinely performed at most canals in south Florida. The quantitative data for SR 841 Canal are displayed in Appendix K and are graphically represented in Figure 46. The standing crop of hydrilla at this canal was usually moderately high, fluctuating around 400 g/m^2 and reaching a high of 710 g/m^2 in November 1979. The minimum standing crop of less than 20 g/m^2 was reached in March 1980, although the standing crop during the previous March had been 370 g/m^2. While as many as 568 insects/m^2 were recorded (February 1979), insect density was usually around 100 insects/m^2 (average for 18 collections of 87 insects/m^2). Snail density was moderate, averaging 124 snails/m^2.

A total of 69 insect species were recorded from SR 841 Canal, the highest species richness for any of the 6 study areas. Not surprisingly, the insect diversity index (Shannon-Weaver) for all 18 collections at this site was the highest (3.075) for all the study areas. However, its average insect diversity of 1.52 for each collection

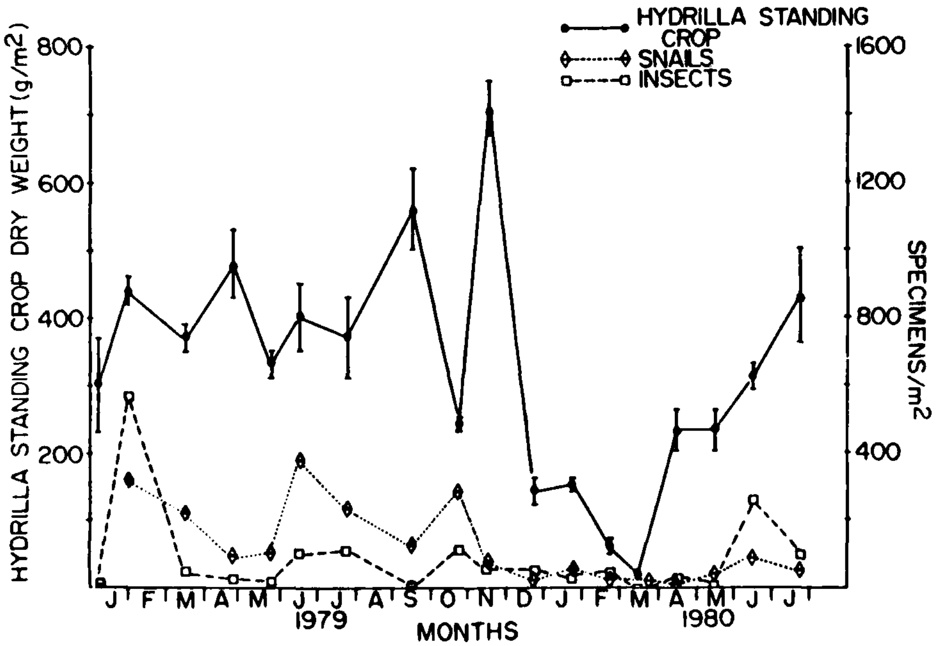

Figure 46. Graph of seasonal changes in the abundance of *Hydrilla verticillata*, insects, and snails at the SR 841 Canal in Collier County, Florida. Although the SR 841 Canal had a high mean standing crop of hydrilla, the insect and snail abundances at the site were only moderate compared with other quantitatively sampled Florida sites

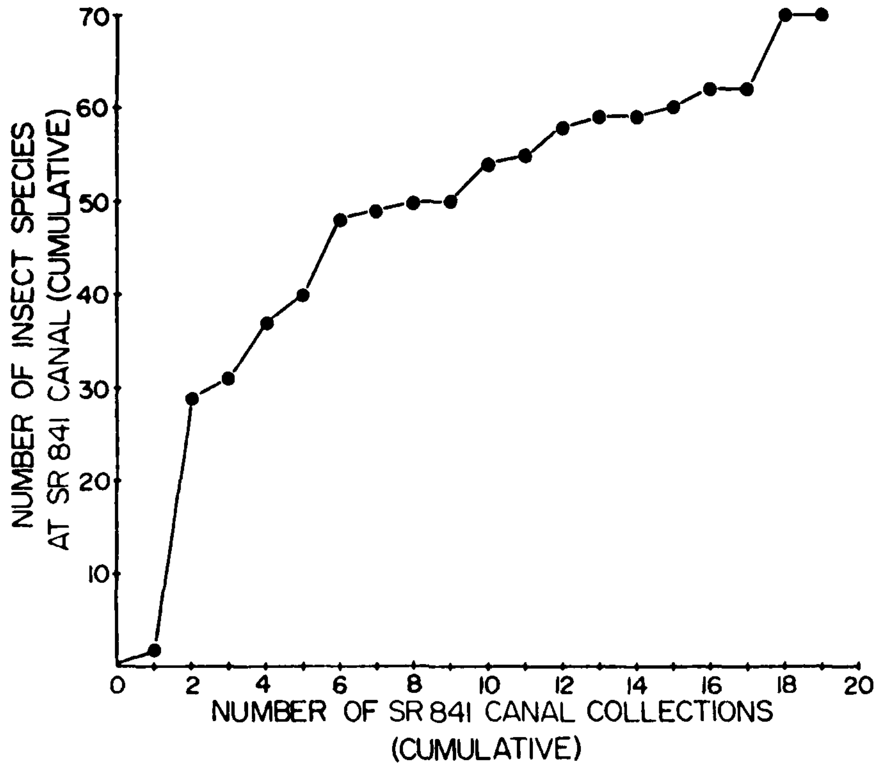

Figure 47. Species accumulation curve for insects collected in association with *Hydrilla verticillata* at the SR 841 Canal, Collier County, Florida. With 69 species, this canal had the highest insect species richness of the six study sites. The contribution of additional insect species by succeeding collections approximates the expectations from an idealized species accumulation curve

ranked it after Lake Jackson, where the collections averaged a Shannon-Weaver insect diversity index of 1.83. Since species richness was lower at Lake Jackson, species evenness, i.e. equal distribution of specimens among the species, must have been lower at SR 841 Canal, indicating a greater dominance of a few species in the collections.

The species accumulation curve for SR 841 insects (Figure 47) shows an excellent, exponential increase in the number of insect species added by the first collections. The first 6 collections produced 48 insect species (70 percent of the final 69 species), but then the next 10 collections added only 13 more insect species.

Comparison of Six Study Sites

Table 2 summarizes the quantitative results at the six study sites. With an average standing crop at 454 g/m^2, Wacissa River maintained a substantially higher hydrilla biomass than any of the other study areas. The hydrilla biomass at oligothrophic Lake Jackson was the lowest by far, averaging only 46 g/m^2 and never exceeding 96 g/m^2. The five 0.125-m^2 subsamples which made up each quantitative collection were frequently highly variable, reflecting the variability of biomass distribution in hydrilla mats. The standard errors (SE) were

Table 2
Comparison of Quantitative Results of the Six Study Sites

Parameter	*Lake Jackson*	*Wacissa River*	*Lake Lochloosa*	*Rodman Reservoir*	*Crystal River*	*SR 841 Canal*
Average sample depth, m	2.5	1.5	2.4	1.4	0.8	1.2
Number of quantitative collections	15	20	15	17	11	18
Hydrilla standing crop, g/m^2 dry wt						
Mean ± avg SE	46 ± 9	454 ± 30	167 ± 22	159 ± 23	117 ± 16	320 ± 33
Min - Max	7 - 96	46 - 1013	47 - 229	10 - 575	14 - 331	18 - 710
Insect density, insects/m^2						
Mean	134	21	485	285	33	87
Min - Max	10 - 867	0 - 162	0 - 2691	19 - 1158	2 - 82	3 - 568
Insects, species/specimens	55/1090	37/264	54/3565	59/2709	21/305	69/867
Shannon-Weaver Insect Diversity						
Avg/collection ± avg SE	1.83 ± 0.09	0.77 ± 0.15	1.21 ± 0.15	1.29 ± 0.10	1.01 ± 0.18	1.52 ± 0.14
Insect diversity/combined collections	2.8/16	2.59/22	1.92/15	1.86/18	1.82/12	3.07/18
Snail density, snails/m^2						
Mean	45	953	82	151	71	124
Min - Max	2 - 139	82 - 3265	13 - 218	14 - 747	6 - 149	10 - 384
Snails, species/specimens	5/367	10/11444	4/688	8/1261	8/594	8/1325

accordingly large. There was also great variability in the average hydrilla standing crop for the monthly samples at each study area. Peak standing crop of hydrilla was frequently 20, 30, or even in excess of 50 times the value of the minimum. The annual peak in biomass usually occurred during summer or early fall, but at some sites peak biomass was reached in the winter. A particular site might have a peak standing crop in the summer one year, and then in the winter during the following year. A regular seasonal pattern in hydrilla biomass peaks and declines was most evident at Wacissa River. Sharp declines of hydrilla biomass occurred at all six sites, usually in winter or early spring. However, the population of hydrilla at SR 841 Canal did not collapse during 1979. The variation of hydrilla biomass cycles between sites and between years at the same site was very great and this sort of variability should be considered in any program of hydrilla control.

Insect densities varied greatly between sites and between collections at the same site. The abundance of insects at a particular site generally seemed to be independent of the amount of hydrilla present, with high numbers being present during winter. Lake Lochloosa's average insect density of 485 insects/m^2 was substantially higher than at any other study site. However, most of these insects belonged to a few chironomid species and, with a total of 54 insect species, Lake Lochloosa ranked only fourth among the six sites for insect species richness. Wacissa River had the lowest average insect density (21 insects/m^2) and the other lotic site, Crystal River, also had very low numbers of insects, averaging 33 insects/m^2.

The Shannon-Weaver Diversity Index for the insects found in each collection was calculated. This index is sensitive to both species richness (number of species) and species evenness (equality of distribution of specimens among the species). Not surprisingly, the sites richest in insect species had the highest diversity index. With 69 total insect species, SR 841 Canal had the highest overall (combined collection) diversity index of 3.07, and the second highest average

collection diversity index of 1.52. Lake Jackson had the highest average collection diversity of 1.83 and the second highest overall diversity at 2.88. Since only 55 insect species had been recorded at Lake Jackson, the consistently high diversity indices at that location indicate high species evenness. Wacissa River had the lowest average diversity index per collection, 0.77, while Crystal River had the lowest overall diversity index, 1.82.

Snail density seemed to track hydrilla biomass in a very general way. Wacissa River had the greatest average snail density — 953 snails/m^2 — and the greatest snail species richness with 10 species. Lake Jackson averaged only 45 snails/m^2 and only 5 species of snails were recorded from there.

SUMMARY

This survey of the insects and other macrofauna associated with hydrilla is the most intensive insect survey yet conducted for a single aquatic plant species. A total of 267 collections of hydrilla and its associated fauna were made at 58 Florida locations. An additional 22 collections from 17 out-of-state hydrilla infestations were also made. Most of the Florida collections (51 percent) were made quantitatively, using a specially designed and constructed sampler which would remove in a vertical section extending from the water's surface down to the hydrosoil, a 0.125-m^2 portion of the hydrilla mat and its associated fauna.

Consequently, this insect survey is also the most extensive field study of hydrilla growth and biomass cycles conducted to date. Six Florida sites, intensively sampled from 1978 through 1980, were selected for analysis and discussion in this report. These six sites included a clear oligotrophic lake, a "swampwater" lake, a mesotrophic reservoir, a drainage canal, and two spring-fed rivers, one of which was estuarine. Of these six study sites, the northernmost site, Lake Jackson in Leon County, was almost 400 airmiles from the most southerly site, a canal in Collier County. Most of the previously published field studies of hydrilla growth and biomass have concentrated on lakes. The few multilake field studies have usually been restricted geographically, and the lakes studied were usually ecologically similar.

Hydrilla has great ecological amplitude, and this is demonstrated by the diversity of locations at which hydrilla was collected during this survey. No statistically significant correlation of hydrilla biomass to specific conductivity (an indirect measure of nutrient content of the water), water depth, or water temperature (or any of the other physical or limnological collection parameters recorded during this survey) was found when the data from all collections were considered together. In estuarine areas, hydrilla could not be found at locations where salinities exceeded 7 ppt. Hydrilla standing crop (total biomass minus root biomass) fluctuated greatly at any given location, with peak hydrilla biomass density at a given location sometimes being in excess of 50 times the lowest biomass density recorded from the same location. While these fluctuations in standing crop showed seasonal trends at some locations, at most sites this seasonal relation was tenuous at best. Although hydrilla biomass maxima

generally seemed to be observed during the summer or early fall, this generalization is not safely applied to particular locations. For example, at Lake Lochloosa, hydrilla biomass peaked in October during 1979, but in July during 1980.

Hydrilla biomass was also highly variable at different sites. Hydrilla standing crop (dry weight) reached a maximum of 1013 g/m^2 at Wacissa River, but never exceeded 100 g/m^2 at Lake Jackson. At "typical" Florida hydrilla infestations such as Rodman Reservoir and Lake Lochloosa, hydrilla standing crop averaged around 160 g/m^2 over the course of 1-1/2 to 2 years.

A total of 59,130 faunal specimens associated with hydrilla were collected during this survey. Their collection, sorting, identification, and cataloging consumed enormous amounts of time. Almost half (48.2 percent) of those specimens were snails. Snail abundance generally seemed to be related to hydrilla biomass. Snails were extremely abundant at one of the lotic study sites (Wacissa River) with their numbers at one time exceeding 3200 snails/m^2. Typical densities at most other locations were usually in the range of 50 to 100 snails/m^2. At least 25 species of snails were recorded. Most appeared to feed on the epiflora associated with hydrilla and little direct damage to living hydrilla tissues was observed.

Over 17,000 insects, belonging to at least 199 species, were recorded during this survey. Of them, 57 percent of the insects collected were midges (Diptera: Chironomidae) and 24.5 percent were caddisflies (Trichoptera). Dragonflies (Odonata), true bugs (Hemiptera), beetles (Coleoptera), and moths (Lepidoptera) were collected at many locations but were not very abundant. Insect densities were highly variable, ranging from no insects in collections from Wacissa River, to 2691 insects/m^2 of hydrilla mat in one Lake Lochloosa collection. Peak insect abundance usually occurred around March, but this was also highly variable. High abundances of insects did not necessarily mean high numbers of insect species. Lake Lochloosa produced 3565 insect specimens, but these included only 55 species. At a drainage canal in south Florida, only 867 insects were collected, but these comprised 69 species.

The richness of insect species associated with hydrilla is far lower than that of aquatic insects associated with waterhyacinth roots, but is substantially higher than that of the insects associated with Eurasian watermilfoil. Analysis of a species accumulation curve constructed from the data for all Florida collections indicates that many additional hydrilla insect species would be recorded, if additional collections continued to be made. However, collecting efficiency would be low, with a predicted species accumulation rate of three additional insect species being found for every ten additional collections in Florida.

Of the almost 200 insect species recorded, probably only 10 percent or so damage hydrilla by their feeding activities. Of these, 5 species of caddisfly (Trichoptera) were the most widespread and abundant. These caddisfly larvae can feed on a wide variety of aquatic vegetation and seem to exhibit little preference for hydrilla. A half-dozen species of moths whose larvae probably feed on hydrilla were recorded in this survey. Of these, *Parapoynx diminutalis*, a recently introduced Asiatic species, is the most abundant. *Parapoynx diminutalis*

appears to prefer hydrilla (at least in the field) and it causes extensive damage to hydrilla. When populations of *P. diminutalis* are high enough, the damage is easily visible, even to untrained observers, and probably negatively impacts on hydrilla's growth and spread. Small numbers of the ephydrid fly, *Hydrellia* spp., were collected. The larvae of *Hydrellia* mine the leaves and stems of hydrilla. This feeding habit made them extremely hard to discover in frozen hydrilla samples, and their relative abundances are probably much higher.

This study clearly illustrates the variability of hydrilla infestations and the aquatic insect and snail communities associated with them. In planning any hydrilla control program, this variability should be considered. It is unrealistic to consider all hydrilla infestations, even in a limited geographic area, as representing a single homogeneous hydrilla community.

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APPENDIX A: CHRONOLOGY OF FOREIGN SEARCHES FOR INSECT ENEMIES OF HYDRILLA (*HYDRILLA VERTICILLATA*)

1971 CIBC initiates search for insect enemies of hydrilla in Pakistan.

1973 Varghese begins studies of insect enemies of hydrilla in Malaysia.

1973 Baloch and Sana-Ullah present preliminary report on natural enemies of hydrilla in Pakistan. Of the eight insect species and two snail species found, only the ephydrid fly *Hydrellia* sp., the moth *Parapoynx diminutalis*, and the weevil *Bagous* sp. nr. *limosus* are considered to be promising biocontrol agents and are being studied further.

1975 Del Fosse et al. discover *Parapoynx diminutalis* in Fort Lauderdale, Florida. This Asian species probably accidentally introduced in a shipment of aquarium plants.

1975 Allen searches in Africa and Indonesia for insect enemies of hydrilla. Results not reported.

1976 Varghese and Singh present final report on studies in Malaysia. Only two insect enemies recorded. One, an aphid species, attacked hydrilla only in greenhouse culture. The other species, a moth, probably *Parapoynx diminutalis*, appears to be fairly specific to hydrilla.

1976 Baloch and Sana-Ullah submit final report on insect enemies of hydrilla in Pakistan. The biology and host-specificity of the three most promising biological control candidates have been studied. A *Bagous* species weevil which feeds on hydrilla tubers is fairly specific. *Parapoynx diminutalis* feeds and reproduces on several aquatic plant species. The leaf-mining *Hydrellia* sp. appeared to be quite specific to hydrilla, but it also fed on *Potamogeton* spp.

1976 Pemberton and Lazor conduct search in Africa for insect enemies. Hydrilla not found until late in 3-month survey and only one possible enemy, the larvae of a midge (Chironomidae), probably in the genus *Polypedilum*, is recorded.

1978 Sanders and Theriot discover a moth, later identified as *Parapoynx rugosalis*, damaging hydrilla in the Panama Canal Zone.

1979 Balciunas and Center study *Parapoynx* prob. *rugosalis* in Panama and find that it feeds primarily on hydrilla and *Najas*.

1980 Buckingham receives permission to bring Panamanian *Parapoynx* into quarantine facilities in Gainesville for further testing. However, the species tested by Balciunas and Center can no longer be located in Panama.

1981 CIBC begins search for insect enemies of hydrilla in East Africa. As of end of 1982, hydrilla had still not been located in Kenya.

1981 Balciunas spends 4 months searching for natural enemies of hydrilla in tropical Asia. Most of the insects previously recorded on hydrilla in Asia are found. Several species of *Bagous* weevils are found damaging hydrilla in India.

1982 Habeck and Bennet make two unsuccessful trips to Panama searching for *Parapoynx rugosalis* and the *Parapoynx* sp. tested by Balciunas and Center.

1982 Balciunas spends 6 months searching for natural enemies of hydrilla in Kenya, India, Southeast Asia, and northern Australia. Several new moth species are found damaging hydrilla, along with approximately 15 species of *Bagous* weevils.

APPENDIX B: FLORIDA HYDRILLA COLLECTIONS

COUNTY	SITE	LOCATION	COLL. NO	DATE
ALACHUA CO.	LAKE LOCHLOOSA	LOCHLOOSA TOWN BOAT RAMP	78206	30JUL1978
ALACHUA CO.	LAKE LOCHLOOSA	LOCHLOOSA TOWN BOAT RAMP	79289	09APR1979
ALACHUA CO.	LAKE LOCHLOOSA	LOCHLOOSA TOWN BOAT RAMP	79302	08MAY1979
ALACHUA CO.	LAKE LOCHLOOSA	LOCHLOOSA TOWN BOAT RAMP	79313	04JUN1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79256	09JAN1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79269	06FEB1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79278	06MAR1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79330	13JUL1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79337	07AUG1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79337	10AUG1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79355	10SEP1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79370	12OCT1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79383	06NOV1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	79399	11DEC1979
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80201	07JAN1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80217	11FEB1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80227	11MAR1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80241	07APR1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80252	06MAY1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80259	09JUN1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80264	08JUL1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80268	17OCT1980
ALACHUA CO.	LAKE LOCHLOOSA	500 METERS FROM SOUTHWEST CORNER	80275	19AUG1980
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79314	04JUN1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79331	15JUL1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79343	10AUG1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79356	10SEP1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79371	12OCT1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79384	06NOV1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	79400	11DEC1979
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	80202	07JAN1980
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	80218	11FEB1980
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	80228	11MAR1980
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK BOAT TRAIL	80242	07APR1980
ALACHUA CO.	ORANGE LAKE	M.K.RAWLING PARK CANAL	79290	09APR1979
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	78218	01SEP1978
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	78235	04OCT1978
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	79257	09JAN1979
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	79270	06FEB1979
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	79279	06MAR1979
ALACHUA CO.	ORANGE LAKE	NEAR CROSS CREEK	79303	08MAY1979
BROWARD CO.	ALLIGATOR ALLEY CANAL	71.2 MILE MARKER	78225	15SEP1978
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	79345	15AUG1979
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	79362	25SEP1979
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	79382	25OCT1979
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	79412	28DEC1979
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	80213	01FEB1980
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	80226	07MAR1980
BROWARD CO.	BROWARD CONDO LAKE	NE OF BROWARD AND UNIV. BLVD. JNCT	80239	04APR1980

COUNTY	SITE	LOCATION	COLL NO	DATE
BROWARD CO.	HOLIDAY PARK CANAL	SOUTH CANAL	78217	30AUG1978
BROWARD CO.	HOLIDAY PARK CANAL	SOUTH CANAL	78243	04DEC1978
BROWARD CO.	HOLIDAY PARK CANAL	SOUTH CANAL	79297	29MAR1979
BROWARD CO.	L LAKE	NEAR NORTH SHORE	78229	21SEP1978
BROWARD CO.	SW 76 AVE CANAL	AT SW 39 ST, DAVIE	78212	21AUG1978
BROWARD CO.	SW 76 AVE CANAL	AT SW 39 ST, DAVIE	78228	21SEP1978
BROWARD CO.	SW 76 AVE CANAL	AT SW 39 ST, DAVIE	79277	07FEB1979
BROWARD CO.	SW 76 AVE CANAL	AT SW 39 ST, DAVIE	80248	17APR1980
BROWARD CO.	US 27 CANAL	LOCK 4 MILES NORTH OF ANDYTOWN	78223	06SEP1978
BROWARD CO.	72 AVE CANAL	NEAR JUNCTION WITH SHERIDAN ST.	78224	06SEP1978
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	78207	31JUL1978
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	78230	04OCT1978
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	78246	08DEC1978
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79262	11JAN1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79274	08FEB1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79319	07JUN1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79329	12JUL1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79341	09AUG1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79369	11OCT1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79406	14DEC1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	79413	09NOV1979
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	80207	10JAN1980
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	80215	11FEB1980
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	80230	12MAR1980
CITRUS CO.	CRYSTAL RIVER	MOUTH OF MILLER'S CREEK	80244	07APR1980
CITRUS CO.	CRYSTAL RIVER	NORTH END OF KING'S BAY	78247	08DEC1978
CITRUS CO.	CRYSTAL RIVER	NORTH END OF KING'S BAY	79263	11JAN1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79264	11JAN1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79275	08FEB1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79283	08MAR1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79294	11APR1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79307	10MAY1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79328	28JUL1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79342	09AUG1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79368	11OCT1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79393	09NOV1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	79405	13DEC1979
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	80208	10JAN1980
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	80216	11FEB1980
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	80231	12MAR1980
CITRUS CO.	CRYSTAL RIVER CANAL	BY THREE SISTERS SPRINGS	80243	07APR1980
CITRUS CO.	HOMOSSASA RIVER	AMONG ISLANDS AT MOUTH	79350	22AUG1979
COLLIER CO.	LAKE TRAFFORD	MIDDLE OF LAKE	[illegible]	[illegible]
COLLIER CO.	LAKE TRAFFORD	MIDDLE OF LAKE	79335	25JUL1979
COLLIER CO.	LAKE TRAFFORD	MIDDLE OF LAKE	79351	30AUG1979
COLLIER CO.	LAKE TRAFFORD	MIDDLE OF LAKE	[illegible]	[illegible]
COLLIER CO.	LAKE TRAFFORD	MIDDLE OF LAKE	79411	[illegible]

COUNTY	SITE	LOCATION	COLL NO	DATE
COLLIER CO.	LAKE TRAFFORD	NEAR WEST SIDE	78226	15FEB1978
COLLIER CO.	LAKE TRAFFORD	NORTH SIDE	79301	26APR1979
COLLIER CO.	LAKE TRAFFORD	SOUTH SIDE	79289	29MAR1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79348	17AUG1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	78214	23AUG1978
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	78239	01NOV1978
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79254	05JAN1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79267	01FEB1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79286	20MAR1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79299	19APR1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79310	17MAY1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79321	14JUN1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79333	18JUL1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79360	13SEP1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79374	19OCT1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79397	20NOV1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	79409	20DEC1979
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	80211	17JAN1980
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	80224	21FEB1980
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	80237	20MAR1980
COLLIER CO.	LOOP ROAD CANAL	3.6 MILES SOUTH OF US 41 JUNCTION	80250	17APR1980
COLLIER CO.	SR 839 CANAL	AT TAMIAMI CANAL JUNCTION	78215	23AUG1978
COLLIER CO.	SR 839 CANAL	AT TAMIAMI CANAL JUNCTION	78240	01NOV1978
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79268	01FEB1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79287	20MAR1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79300	19APR1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79311	17MAY1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79322	14JUN1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79334	18JUL1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79349	17AUG1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79361	13SEP1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79375	19OCT1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79398	20NOV1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	79410	20DEC1979
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80212	17JAN1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80225	21FEB1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80238	20MAR1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80251	17APR1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80257	15MAY1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80262	16JUN1980
COLLIER CO.	SR 841 CANAL	FOOTBRIDGE, 2.8 MI NORTH OF US 41	80267	18JUL1980
COLLIER CO.	SR 841 CANAL	NORTH OF JUNCTION WITH SR 837	78216	23AUG1978
COLLIER CO.	SR 841 CANAL	NORTH OF JUNCTION WITH SR 837	78241	01NOV1978
COLLIER CO.	SR 841 CANAL	NORTH OF JUNCTION WITH SR 837	79255	05JAN1979
DADE CO.	NW 25 ST. CANAL	AT NW 24 AVE, MIAMI	78211	[illegible]
DADE CO.	NW 25 ST. CANAL	AT NW 24 AVE, MIAMI	[illegible]	[illegible]
DADE CO.	NW 25 ST. CANAL	AT NW 24 AVE, MIAMI	[illegible]	[illegible]
DADE CO.	NW 25 ST. CANAL	AT NW 24 AVE, MIAMI	[illegible]	[illegible]
DADE CO.	NW 25 ST. CANAL	AT NW 24 AVE, MIAMI	[illegible]	[illegible]

COUNTY	SITE	LOCATION	COLL NO	DATE
DADE CO.	NW 25 ST. CANAL	AT NW 74 AVE, MIAMI	79395	20NOV1979
DADE CO.	NW 25 ST. CANAL	AT NW 74 AVE, MIAMI	79407	20DEC1979
DADE CO.	NW 25 ST. CANAL	AT NW 74 AVE, MIAMI	80209	17JAN1980
DADE CO.	NW 25 ST. CANAL	AT NW 74 AVE, MIAMI	80222	21FEB1980
DADE CO.	NW 25 ST. CANAL	AT NW 74 AVE, MIAMI	80235	20MAR1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	78213	22AUG1978
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	78238	01NOV1978
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79253	05JAN1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79266	01FEB1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79285	20MAR1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79298	19APR1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79309	17MAY1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79320	14JUN1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79332	18JUL1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79347	17AUG1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79359	13SEP1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79373	19OCT1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79396	20NOV1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	79408	20DEC1979
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GFNERAL STORE	80210	17JAN1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80223	21FEB1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80236	20MAR1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80249	17APR1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80256	15MAY1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80261	16JUN1980
DADE CO.	TAMIAMI CANAL	MICCOSUKEE GENERAL STORE	80266	18JUL1980
GLADES CO.	BIG BASS LODGE CANAL	LAKEPORT	78221	06SEP1978
GLADES CO.	LAKE HICPOCHEE	NE END OF LAKE AT MOOREHAVEN CANAL	78222	06SEP1978
HENDRY CO.	CALOOSAHATCHEE TRIB	1 MILE WEST OF ORTONA LOCK NO SR 80	78227	15SEP1978
HILLSBOROUGH CO.	TAMPA FAIRGROUND PONDS	MIDDLE POND	78209	01AUG1978
HILLSBOROUGH CO.	TAMPA FAIRGROUND PONDS	NORTH POND	78208	01AUG1978
HILLSBOROUGH CO.	TAMPA FAIRGROUND PONDS	SOUTH POND	78210	01AUG1978
JEFFERSON CO.	WACISSA RIVER	SWIM AREA AT HEAD SPRINGS	78203	28JUL1978
JEFFERSON CO.	WACISSA RIVER	SWIM AREA AT HEAD SPRINGS	78244	06DEC1978
JEFFERSON CO.	WACISSA RIVER	SWIM AREA AT HEAD SPRINGS	79259	10JAN1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79271	07FEB1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79280	07MAR1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79291	10APR1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79304	09MAY1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79316	06JUN1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79324	10JUL1979
JEFFFRSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79339	08AUG1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79353	06SEP1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79364	09OCT1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	[illegible]	[illegible]

COUNTY	SITE	LOCATION	COLL NO	DATE
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	79403	12DEC1979
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80204	07JAN1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80220	12FEB1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80233	13MAR1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80246	08APR1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80254	07MAY1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80255	07MAY1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80260	11JUN1980
JEFFERSON CO.	WACISSA RIVER	400 METERS BELOW SWIM AREA	80265	09JUL1980
JEFFERSON CO.	WACISSA RIVER	420 METERS BELOW SWIM AREA	79387	07NOV1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	78245	06DEC1978
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79260	10JAN1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79272	07FEB1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79281	07MAR1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79292	10APR1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79305	09MAY1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79317	06JUN1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79325	10JUL1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79338	08AUG1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79354	07SEP1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79365	09OCT1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79388	08NOV1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	79404	12DEC1979
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	80205	07JAN1980
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	80219	12FEB1980
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	80232	13MAR1980
LEON CO.	LAKE JACKSON	WEST SIDE BY US 27	80245	08APR1980
LEVY CO.	SUWANNEE RIVER	MANATEE SPRINGS BOARDWALK	78205	29JUL1978
LEVY CO.	SUWANNEE RIVER	MOUTH OF MANATEE SPRINGS	78204	29JUL1978
MARION CO.	INGLIS RESERVOIR	EAST END	78248	08DEC1978
MARION CO.	INGLIS RESERVOIR	MOUTH OF WITHLACOOCHEE	78231	03OCT1978
MARION CO.	SALT SPRINGS	BOAT DOCK	78219	01SEP1978
MARION CO.	SALT SPRINGS	BEGINNING OF SPRING RUN	78232	03OCT1978
MARION CO.	SALT SPRINGS	BEGINNING OF SPRING RUN	78249	08DEC1978
MARION CO.	SILVER GLEN SPRINGS	BOAT RAMP	78233	03OCT1978
OKEECHOBEE CO.	MARSHY LAKE	1 MILE WEST OF US 98 JUNCTION	78220	05SEP1978
OSCEOLA CO.	SMALL STREAM	CROSSING TURNPIKE AT 155 MI MARKER	79344	12AUG1979

COUNTY	SITE	LOCATION	COLL_NO	DATE
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	78234	04OCT1978
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	78250	08DEC1978
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79265	11JAN1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79276	08FEB1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79284	08MAR1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79296	11APR1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79394	12NOV1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	79401	11DEC1979
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80203	08JAN1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80214	08FEB1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80229	11MAR1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80240	06APR1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80253	06MAY1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80258	09JUN1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80263	07JUL1980
PUTNAM CO.	RODMAN RESERVOIR	END OF RODMAN REC AREA BOAT TRAIL	80274	19AUG1980
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79295	11APR1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79308	10MAY1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79315	05JUN1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79327	11JUL1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79336	07AUG1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79357	10SEP1979
PUTNAM CO.	RODMAN RESERVOIR	START OF RODMAN REC AREA BOAT TRAIL	79367	10OCT1979
SARASOTA CO.	MYAKKA RIVER	MYAKKA STATE PARK BRIDGE	78251	21DEC1978
WAKULLA CO.	ST. MARKS RIVER	END OF OLD PIER, SOUTH OF NEWPORT	80206	09JAN1980
WAKULLA CO.	ST. MARKS RIVER	END OF OLD PIER, SOUTH OF NEWPORT	80234	13MAR1980
WAKULLA CO.	ST. MARKS RIVER	END OF OLD PIER, SOUTH OF NEWPORT	80247	08APR1980
WAKULLA CO.	ST. MARKS RIVER	JUST ABOVE SHIPYARD ON THE NE SIDE	79318	07JUN1979
WAKULLA CO.	ST. MARKS RIVER	SOUTH OF NATURAL BRIDGE ST. PARK	79261	10JAN1979
WAKULLA CO.	ST. MARKS RIVER	US 98 BOAT RAMP	79258	10JAN1979
WAKULLA CO.	ST. MARKS RIVER	US 98 BOAT RAMP	79273	07FEB1979
WAKULLA CO.	ST. MARKS RIVER	1/2 MILE BELOW US 98	79306	09MAY1979
WAKULLA CO.	ST. MARKS RIVER	125 METERS BELOW NEWPORT SHIPYARD	79402	12DEC1979
WAKULLA CO.	ST. MARKS RIVER	200 METERS BELOW NEWPORT SHIPYARD	79326	11JUL1979
WAKULLA CO.	ST. MARKS RIVER	200 METERS BELOW NEWPORT SHIPYARD	79340	08AUG1979
WAKULLA CO.	ST. MARKS RIVER	200 METERS BELOW NEWPORT SHIPYARD	79366	09OCT1979
WAKULLA CO.	ST. MARKS RIVER	200 METERS BELOW NEWPORT SHIPYARD	79385	07NOV1979
WAKULLA CO.	ST. MARKS RIVER	200 METERS BELOW NEWPORT SHIPYARD	80221	12FEB1980
WAKULLA CO.	ST. MARKS RIVER	200 YARDS BELOW US 98 BRIDGE	79282	07MAR1979
WAKULLA CO.	ST. MARKS RIVER	500 METERS BELOW POWERLINE	79293	10APR1979
WAKULLA CO.	ST. MARKS RIVER	500 YARDS BELOW NEWPORT SHIPYARD	79353	06SEP1979

APPENDIX C: NON-FLORIDA HYDRILLA COLLECTIONS

STATE	COUNTY	SITE	LOCATION	COLL_NO	DATE
CALIFORNIA	IMPERIAL CO.	ALL AMERICAN CANAL	MEADOWS ROAD BRIDGE	78236	23OCT1978
CALIFORNIA	IMPERIAL CO.	SHELDON RESERVOIR		78237	24OCT1978
GEORGIA	SEMINOLE CO.	LAKE SEMINOLE	FISH POND DRAIN	78201	28JUL1978
GEORGIA	SEMINOLE CO.	LAKE SEMINOLE	FISH POND DRAIN	79389	08NOV1979
GEORGIA	SEMINOLE CO.	LAKE SEMINOLE	HIGHWAY BRIDGE, CYPRESS POND	78202	28JUL1978
GEORGIA	SEMINOLE CO.	LAKE SEMINOLE	SEMINOLE STATE PARK	79391	08NOV1979
GEORGIA	SEMINOLE CO.	LEWIS POND	AT CANAL TO RAYE LAKE	79390	08NOV1979
LOUISIANA	TERREBONNE PARRISH	SR 24 CANAL	BY BROADMOOR WATER TOWER	79381	31OCT1979
LOUISIANA	TERREBONNE PARRISH	SR 24 CANAL	2 MILES SOUTH OF GRAY ROAD	78242	14NOV1978
TEXAS	HAYS CO.	FISH HATCHERY POND	CITY OF SAN MARCOS	79376	24OCT1979
TEXAS	HAYS CO.	SAN MARCOS RIVER	AT I-35	79377	24OCT1979
TEXAS	HAYS CO.	SAN MARCOS RIVER	AT I-35	80272	23OCT1980
TEXAS	HAYS CO.	SAN MARCOS RIVER	SW TEXAS	80269	23OCT1980
TEXAS	HAYS CO.	SAN MARCOS RIVER	UNIVERSITY	80270	23OCT1980
TEXAS	HAYS CO.	SAN MARCOS RIVER	PICNIC AREA	80271	23OCT1980
TEXAS	MONTGOMERY CO.	LAKE CONROE	ATKINS CREEK AREA	79378	29OCT1979
TEXAS	MONTGOMERY CO.	LAKE CONROE	SEVEN COVES	79379	29OCT1979
TEXAS	POLK CO.	LAKE LIVINGSTON	OAK TERRACE BOAT LAUNCH	79380	29OCT1979
PANAMA	CANAL ZONE	LAKE GATUN	DUMP 4.5, NEAR GAMBOA	80273	31OCT1980
PANAMA	CANAL ZONE	RIO CHAGRES	1 MILE EAST OF	79312	23MAY1979
PANAMA	CANAL ZONE	RIO CHAGRES	GAMBOA RR BRIDGE	80276	04NOV1980
PANAMA	CANAL ZONE	RIO CHAGRES	BY GAMBOA GOLF COURSE	80277	29OCT1980

APPENDIX D: FORTRAN PROGRAM FOR CALCULATING SPECIES DIVERSITY INDICES

SHANNON-WEAVER DIVERSITY INDEX, SIMPSON'S DIVERSITY INDEX AND BRILLOUINS'S INDEX.

THIS PROGRAM WAS WRITTEN BY JOSEPH K. BALCIUNAS, GRADUATE STUDENT, UNIVERSITY OF FLORIDA,(SEE APPENDIX A. IN 'SPECIES ABUNDANCE RELATIONSHIPS OF AQUATIC INSECTS IN MONOTYPIC WATERHYACINTH COMMUNITIES IN FLORIDA, WITH SPECIAL EMPHASIS ON FACTORS AFFECTING DIVERSITY', A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA, GAINESVILLE, 1977). THE ORIGINAL INTERACTIVE TERMINAL PROGRAM HAS BEEN MODIFIED FOR BATCH JOBS BY MARC C. MINNO AND J.K.BALCIUNAS, AREC, 3205 SW COLLEGE AVE, FT. LAUDERDALE, FL 33314, 1983.
THE ALGORITHMS USED ARE:
1) SHANNON-WEAVER INDEX:

$$H' = -\sum_{i=1}^{s} P_i \text{ LOG } P_i$$

where P_i is the proportion of the total specimens comprised by the i th species or $P_i = n_i/N$.

2) SIMPSON'S INDEX:

$$D = 1 - \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N - 1)}$$

where N is the total number of specimens, n_i is number of specimens in the i th species, and s is the number of specimens in the sample.

3) BRILLOUIN'S INDEX:

$$H = 1/N \ \log(N! / n_1! \, n_2! \ldots n_s!)$$

NATURAL LOGS ARE USED IN THIS PROGRAM.

DATA DECK STRUCTURE:
1) 'COLLNO' IS THE COLLECTION NUMBER IDENTIFYING THE SAMPLE.
'N' IS THE NUMBER OF SPECIMENS / SPECIES.
'NTOT' IS THE TOTAL NUMBER OF SPECIMENS IN THE SAMPLE.
'TOTSPP' IS THE NUMBER OF SPECIES IN THE SAMPLE.
2) FIRST DATA CARD CONTAINS THE VARIABLES 'COLLNO' (ENTERED IN COLUMNS 1-6), BLANK, 'NTOT' (ENTERED IN COLUMNS 8-12), BLANK, AND 'TOTSPP' (ENTERED IN COLUMNS 14-18).
FOLLOWING DATA CARDS CONTAIN THE VARIABLE 'N' (ENTERED IN 15I5 FORMAT).
A CARD WITH ZERO PUNCHED IN COLUMN 6 ENDS THE DATA DECK.

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C     LIMITS:
C         1. 'COLLNO', 'NTOT', 'TOTSPP'  AND THE SPECIMEN VALUES OF 'N' ARE
C            RIGHT JUSTIFIED INTEGER VALUES.  IF THE VALUE
C            ASSIGNED TO 'NTOT' DIFFERS FROM THE TOTAL GENERATED FOR
C            'N', AN ERROR MESSAGE IS PRINTED AND 'NTOT' MUST BE
C            RECALCULATED.
C         2. BRILLOUINS INDEX FOR NTOT > 50 CANNOT BE CALCULATED SINCE
C            INTEGER FACTORIALS > 50! MAY EXCEED RANGE OF REAL NUMBER LIMITS.
C         3. THE DIVERSITY OF SAMPLES CONTAINING AT LEAST TWO SPECIES
C            CAN BE ANALYZED WITH THIS PROGRAM.
C
      REAL  P, PSUM, D, HS, HB, DSUM, T
      INTEGER COLLNO, N, NTOT, TOTSPP, SUM, NF
      DIMENSION N(1000),NF(1000)
  1   CONTINUE
      READ(5,100) COLLNO,NTOT,TOTSPP
  100 FORMAT (1X,I5,1X,I5,1X,I5)
      IF (COLLNO .EQ. 0)GO TO 50
      T=NTOT
      SUM=0
      READ(5,101) (N(I),I=1,TOTSPP)
  101 FORMAT (15I5)
      WRITE(6,201) COLLNO
  201 FORMAT (1X,'SPECIMEN VALUES FOR COLLECTION ', I5)
      WRITE(6,202) (N(I),I=1,TOTSPP)
  202 FORMAT (1X, 15I5)
      DO 8 I=1,TOTSPP
      SUM=SUM+N(I)
  8   CONTINUE
      IF(SUM.EQ.T)GO TO 20
      WRITE(6,102) COLLNO,SUM,NTOT
  102 FORMAT (1X,'VALUE OF TOTAL NUMBER OF SPECIMENS INCORRECT',
     1 ' FOR COLLNO ', I5, 10X,'TOTAL = ', I5,' NTOT = ', I5)
      GO TO 1
  20  WRITE(6,103) TOTSPP,SUM,COLLNO
  103 FORMAT (1X,' NUMBER OF SPECIES = ', I5,
     1 ' AND TOTAL NUMBER OF SPECIMENS = ',
     2 I5,1X,' FOR COLLNO ', I5)
C
C     COMPUTE SIMPSONS INDEX
C
      DSUM=0
      DO 12 I=1,TOTSPP
      DSUM=DSUM+N(I)*(N(I)-1)
  12  CONTINUE
      D=1-DSUM/(NTOT*(NTOT-1))
C
C     COMPUTE SHANNON-WEAVER INDEX
C
      PSUM=0
      DO 10 I=1,TOTSPP
      P=N(I)/T
      PSUM=P*ALOG(P)+PSUM
  10  CONTINUE
      HS=-PSUM
```

```
C
C     COMPUTE BRILLOUINS INDEX
C
      IF (T .GT. 49) GO TO 105
      J=1
      I=1
      TF=T
    2 TF=TF*(T-J)
      J=J+1
      IF(T-J)3,3,2
    3 NF(I)=N(I)
      IF(N(I)-1)16,16,17
   16 NF(I)=1
      GO TO 5
   17 J=1
    4 NF(I)=NF(I)*(N(I)-J)
      J=J+1
      IF (N(I)-J)5,5,4
    5 I=I+1
      IF(I.LE.TOTSPP)GO TO 3
      PROD=1
      DO 11 I=1,TOTSPP
      PROD=PROD*NF(I)
   11 CONTINUE
      NSKIP=0
      IF((TF/PROD) .LT. NSKIP) GO TO 105
      HB=(1/T)*(ALOG(TF/PROD))
      WRITE(6,104) COLLNO,HS,HB,D
  104 FORMAT (1X,'COLLNO = ', I5,4X,' SHANNON WEAVER INDEX = ', F7.4,
     1 4X,' BRILLOUINS INDEX = ', F7.4,4X,' SIMPSONS INDEX = ', F7.4)
      GO TO 1
  105 WRITE(6,106) COLLNO,HS,D
  106 FORMAT (1X,'COLLNO = ', I5,4X,' SHANNON WEAVER INDEX = ', F7.4,
     1 4X,' BRILLOUINS INDEX CANNOT BE CALCULATED',4X,
     2 ' SIMPSONS INDEX = ', F7.4)
      GO TO 1
   50 CONTINUE
      STOP
      END
```

APPENDIX E: *HYDRILLA VERTICILLATA* COLLECTION SITE DATA

COLL_NO	DEPTH	MAT_DPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	FLNT_SP2	SF2_DWGT	FLNT_SP3	SF3_DWGT	LDHG_TOP	LDHG_MID	LDHG_BOT	SDHG_TOP	SDHG_MID	SDHG_BOT
78201	2.40	0.6	.	.	.	.	36.5	NONE	.	NONE	.	.	.	.	.	.	.
78202	1.20		.	.	.	.	72.7	NONE	.	NONE	.	.	.	.	.	.	.
78203	0.61	TOP	22.0	.	.	.	40.7	NONE	.	NONE	.	.	.	.	.	.	.
78204	2.30	0.5	24.0	.	.	.	82.0	NONE	.	NONE	.	.	.	.	.	.	.
78205	2.00	0.9	23.0	.	.	.	49.6	NONE	.	NONE	.	.	.	.	.	.	.
78206	1.10	TOP	30.5	.	.	.	94.7	NONE	.	NONE	.	.	.	.	.	.	.
78207	1.20	TOP	28.0	.	.	.	134.4	NONE	.	NONE	.	.	.	.	.	.	.
78208	0.61	TOP	27.0	.	.	.	102.4	NONE	.	NONE	.	.	.	.	.	.	.
78209	0.61	TOP	28.5	.	.	.	39.5	NONE	.	NONE	.	.	.	.	.	.	.
78210	0.50	TOP	29.0	.	.	.	55.4	NONE	.	NONE	.	.	.	.	.	.	.
78211	1.00	TOP	29.5	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
78212	0.45		28.0	.	.	.	109.6	NONE	.	NONE	.	.	.	.	.	.	.
78213	1.00		32.0	.	.	.	134.7	NONE	.	NONE	.	1.1	1.2	1.2	1.1	1.2	1.2
78214	1.00		30.0	.	.	.	225.5	NONE	.	NONE	.	1.3	1.5	1.4	1.2	1.1	1.2
78215	.		28.0	.	.	.	250.3	NONE	.	NONE	.	2.2	2.1	2.4	1.6	1.6	1.7
78216	1.00		31.5	.	.	.	307.9	NONE	.	NONE	.	2.4	2.3	2.4	1.5	1.6	1.4
78217	.		.	.	.	.	105.6	NONE	.	NONE	.	1.1	1.3	1.6	2.2	2.4	2.4
78218	1.00	TOP	29.5	.	.	.	43.9	NONE	.	NONE	.	1.1	1.3	1.5	1.2	1.2	1.3
78219	1.00	0.6	25.0	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
78220	0.70		29.0	.	.	.	80.0	NONE	.	NONE	.	1.1	1.2	1.2	1.3	1.3	1.2
78221	0.45		30.0	.	.	.	82.5	NONE	.	NONE	.	1.2	1.3	1.6	1.3	1.4	1.4
78222	0.55		35.0	.	.	.	64.0	NONE	.	NONE	.	1.7	1.8	1.6	1.2	1.5	1.4
78223	1.00		29.5	.	.	.	90.5	NONE	.	NONE	.	1.1	1.4	1.6	1.6	1.6	1.4
78224	1.00	TOP	32.0	.	.	.	115.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
78225	1.00		30.0	.	.	.	281.8	NONE	.	NONE	.	1.1	1.5	1.7	1.1	1.6	1.4
78226	0.90		29.5	.	.	.	132.2	NONE	.	NONE	.	3.3	3.6	3.8	1.6	1.7	1.7
78227	0.70		30.0	.	.	.	53.4	NONE	.	NONE	.	1.3	2.0	2.2	1.3	1.6	1.8
78228	.		30.0	.	.	.	83.6	NONE	.	NONE	.	1.2	1.8	1.8	1.4	1.8	1.7
78229	2.40	0.6	32.0	.	.	.	153.0	NONE	.	NONE	.	1.0	1.7	1.8	1.2	1.6	1.6
78230	1.00	BEL	24.5	0.0	600	.	142.8	NONE	.	NONE	.	1.0	1.4	1.4	1.0	1.3	1.3
78231	0.90		25.0	0.0	410	.	74.3	NONE	.	NONE	.	1.0	1.5	1.5	1.0	1.0	1.0
78232	0.90	0.4	24.0	3.3	6000	.	128.2	NONE	.	NONE	.	1.0	1.4	1.5	1.0	1.1	1.0
78233	0.75	.15	23.5	1.0	2000	.	128.7	NONE	.	NONE	.	1.6	1.5	1.7	1.1	1.5	1.6
78234	2.10	TOP	24.3	0.0	197	.	85.2	NONE	.	NONE	.	1.2	1.4	1.6	1.0	1.4	1.3
78235	2.30	TOP	25.0	0.0	.	.	92.2	NONE	.	NONE	.	1.0	1.5	1.2	1.0	1.5	1.2
78236	1.00	TOP	.	.	.	.	179.7	NONE	.	NONE	.	1.0	1.4	1.4	1.0	1.3	1.2
78237	.		.	.	.	.	485.2	NONE	.	NONE	.	1.0	1.5	1.5	1.1	1.5	1.3
78238	.		28.0	0.0	168	.	104.0	NONE	.	NONE	.	1.2	1.7	1.8	1.2	1.6	1.6
78239	0.70	TOP	26.7	0.0	325	.	97.0	NONE	.	NONE	.	1.0	1.4	1.4	1.0	1.5	1.3
78240	2.00		27.5	0.5	1000	.	219.9	NONE	.	NONE	.	1.2	1.6	1.7	1.2	1.4	1.4
78241	.		28.0	0.0	165	.	431.2	NONE	.	NONE	.	1.0	1.4	1.4	1.1	1.5	1.4
78242	1.00		24.0	0.0	410	.	85.0	NONE	.	NONE	.	1.0	1.5	1.6	1.0	1.1	1.2
78243	1.50	TOP	25.0	0.0	750	.	87.8	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
78244	0.75	TOP	25.0	0.0	215	1551.0	64.4	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
78245	2.00	0.5	19.0	0.0	25	1542.0	22.5	HYPERICUM	0.3	CERATOPHYLLUM DEMERSUM	0.2	1.0	1.0	.	1.0	1.0	.
78246	1.00	0.5	23.5	0.5	1050	282.1	14.9	CERATOPHYLLUM DEMERSUM	15.3	MYRIOPH HETEROPHYLLUM	10.0	1.0	.	.	1.0	.	.
78247	1.80	0.2	23.5	0.0	700	654.0	30.4	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
78248	0.85	0.5	25.5	0.0	230	285.5	7.2	CERATOPHYLLUM DEMERSUM	4.7	NONE	.	1.0	1.0	.	1.0	1.0	.

COLL_NO	DEPTH	MAT_DEPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	PLNT_SP2	SP2_DWGT	PLNT_SP3	SP3_DWGT	LDMG_TOP	LDMG_MID	LDMG_BOT	SDMG_TOP	SDMG_MID	SDMG_BOT
78249	0.75	0.3	24.0	3.8	7000	1478.5	92.4	MYRIOPH HETEROPHYLLUM	0.3	NONE	.	1.0	.	.	1.0	.	.
78250	2.00	BEL	21.0	0.0	265	2849.2	153.1	NAJAS	18.3	POTAMOGETON ILLINOENSIS	0.2	2.6	2.6	2.6	1.8	1.8	1.8
78251	0.45	TOP	21.5	0.0	265	556.0	27.8	NONE	.	NONE	.	1.0	1.0	.	1.0	1.0	.
78252	1.00	TOP	23.5	0.0	475	1860.7	128.8	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79253	1.30		19.5	0.0	215	26910.8	209.5	NONE	.	NONE	.	1.4	1.4	1.4	1.0	1.0	1.0
79254	0.80	TOP	19.0	0.0	350	955.2	70.8	NONE	.	NONE	.	2.6	3.3	3.5	1.1	1.3	1.3
79255	2.00	0.2	19.0	0.0	360	3885.0	190.0	NAJAS GUADALUPENSIS	0.4	NONE	.	1.9	1.9	1.9	1.0	1.0	1.0
79256	1.40	TOP	11.0	0.0	60	886.1	44.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79257	1.70	BEL	11.0	0.0	60	154.3	8.0	NONE	.	NONE	.	1.0	1.5	.	1.0	1.0	.
79258	0.45	TOP	14.0	0.0	150	639.9	33.5	VALLISNERIA AMERICANA	0.8	NONE	.	1.8	1.7	1.5	1.4	1.6	1.6
79259	0.70	TOP	18.0	0.0	200	1506.6	86.9	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79260	2.00	BOT	18.0	0.0	20	251.4	67.3	MYRIOPH SPICATUM	9.1	HYPERICUM	0.3	1.0	1.0	1.0	1.0	1.0	1.0
79261	0.90	TOP	15.0	0.0	150	2346.5	161.7	EGERIA DENSA	0.2	VALLISNERIA AMERICANA	0.1	1.5	1.4	1.4	1.2	1.2	1.2
79262	1.00	BOT	19.0	0.5	850	160.4	13.3	VALLISNERIA AMERICANA	5.9	CERATOPHYLLUM DEMERSUM	3.3	1.0	.	.	1.0	.	.
79263	1.20	0.5	20.0	0.5	1150	233.6	12.5	ALGAE	8.8	VALLISNERIA AMERICANA	0.7	1.1	1.2	1.3	1.1	1.2	1.4
79264	1.70	TOP	20.5	0.0	185	1041.7	57.1	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79265	2.00	TOP	12.0	0.0	235	1352.2	90.5	NAJAS GUADALUPENSIS	0.2	CERATOPHYLLUM DEMERSUM	0.2	1.0	1.0	1.0	1.0	1.0	1.0
79266	.		18.5	0.0	200	225.8	29.2	NAJAS GUADALUPENSIS	5.8	VALLISNERIA AMERICANA	0.1	2.8	3.1	3.1	1.5	1.5	1.5
79267	2.00		19.0	0.0	360	903.6	68.1	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79268	1.30	0.1	19.5	0.0	370	2991.3	272.3	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79269	3.10	TOP	12.5	0.0	80	553.8	34.1	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79270	2.00	BOT	12.5	0.0	60	1219.4	80.0	CERATOPHYLLUM DEMERSUM	0.7	NONE	.	1.3	1.3	1.3	1.0	1.0	1.0
79271	1.50	TOP	17.0	0.0	150	4358.2	348.9	EGERIA DENSA	1.8	NONE	.	1.4	1.1	1.4	1.0	1.0	1.0
79272	2.50		10.5	0.0	20	236.1	12.5	MYRIOPH SPICATUM	46.3	PISTIA STRATIOTES	8.0	1.0	1.2	1.2	1.0	1.2	1.2
79273	.		13.0	0.0	90	840.1	59.3	VALLISNERIA AMERICANA	15.2	NAJAS GUADALUPENSIS	0.1	1.3	1.4	1.5	1.8	1.9	1.9
79274	0.50	TOP	18.5	0.5	1150	1009.5	105.3	CERATOPHYLLUM DEMERSUM	7.4	NAJAS GUADALUPENSIS	1.8	1.4	1.4	1.4	1.4	1.4	1.4
79275	1.30	TOP	21.0	0.0	240	950.2	73.5	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79276	.	0.3	14.5	0.0	240	519.1	30.0	NONE	.	NONE	.	1.4	1.2	1.2	1.2	1.0	1.0
79277	0.55	TOP	26.0	0.0	570	854.4	68.2	NONE	.	NONE	.	1.2	.	.	1.0	.	.
79278	3.20		17.0	0.0	65	1361.2	73.7	NONE	.	NONE	.	1.0	1.0	1.0	1.3	1.3	1.3
79279	.		17.3	0.0	80	539.3	25.1	ALGAE	21.5	NONE	.	1.7	2.0	2.0	1.1	1.1	1.3
79280	1.70	.03	20.0	0.0	200	2043.2	142.2	EGERIA DENSA	0.7	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79281	.		17.5	0.0	23	.	.	HYPERICUM	0.7	NAJAS GUADALUPENSIS	0.1	1.0	1.0	1.0	1.0	1.0	1.0
79282	1.60	0.3	17.5	0.0	155	1082.4	84.8	NONE	.	NONE	.	2.1	2.1	2.1	1.8	1.8	1.8
79283	.	0.5	22.0	0.0	200	518.9	38.9	NONE	.	NONE	.	1.2	1.2	1.2	1.2	1.2	1.2
79284	.		18.5	0.0	285	1791.8	122.1	CERATOPHYLLUM DEMERSUM	.	VALLISNERIA AMERICANA	.	2.5	2.8	2.8	1.3	1.3	1.3
79285	2.00		22.5	0.3	750	469.0	47.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79286	0.50	TOP	22.0	0.0	385	427.6	37.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79287	1.10	TOP	22.5	0.0	385	2369.0	229.5	NAJAS GUADALUPENSIS	1.0	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79288	0.90	TOP	21.5	0.0	300	1090.8	63.2	EICHHORNIA CRASSIPES	0.7	PISTIA STRATIOTES	0.5	1.0	1.0	1.0	1.5	1.5	1.5
79289	.		22.0	0.0	90	1857.3	108.4	NONE	.	NONE	.	1.3	1.3	1.3	1.8	1.8	1.7
79290	1.00	TOP	22.0	0.0	100	838.3	58.0	ALGAE	1.3	NONE	.	1.5	1.5	1.5	1.5	1.5	1.5
79291	1.70	TOP	21.5	0.0	210	3153.6	210.8	EGERIA DENSA	0.8	NONE	.	1.2	1.2	1.2	1.3	1.3	1.3
79292	3.00	BOT	22.5	0.0	35	985.5	46.8	MYRIOPH SPICATUM	13.8	HYPERICUM	0.2	1.5	1.5	1.5	1.4	1.5	1.5

COLL_NO	DEPTH	MAT_DPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	FLNT_SP2	SP2_DWGT	FLNT_SP3	SP3_DWGT	LDMG_TOP	LDMG_MID	LDMG_BOT	SDMG_TOP	SDMG_MID	SDMG_BOT
79293	2.00	TOP	.	0.0	220	446.4	48.0	CERATOPHYLLUM DEMERSUM	22.0	VALLISNERIA AMERICANA	3.0	1.0	1.0	1.0	1.0	1.0	1.0
79294	.		.	0.0	240	102.3	8.4	NONE	.	NONE	.	4.0	4.0	4.0	1.6	1.6	1.6
79295	1.00	TOP	.	0.0	405	1300.0	86.6	CERATOPHYLLUM DEMERSUM	0.5	NONE	.	1.8	1.8	1.8	1.9	1.9	1.9
79296	2.50	BEL	.	0.0	400	1715.0	105.0	NONE	.	NONE	.	2.0	2.0	2.0	2.3	2.3	2.4
79297	.		.	.	.	449.5	32.8	NONE	.	NONE	.	3.2	3.4	3.4	1.4	1.5	1.3
79298	2.60	TOP	.	0.0	470	1288.5	75.1	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.4	1.4
79299	1.00	TOP	.	0.0	600	557.2	49.4	NAJAS GUADALUPENSIS	0.1	NONE	.	1.1	1.1	1.1	1.4	1.4	1.4
79300	0.40	TOP	.	0.0	390	2969.5	297.5	NONE	.	NONE	.	2.1	2.1	2.1	2.0	2.0	2.0
79301	2.00	BEL	.	0.4	700	1897.1	190.9	PISTIA STRATIOTES	7.2	CERATOPHYLLUM DEMERSUM	0.3	1.0	1.0	1.0	1.0	1.0	1.0
79302	.		.	0.0	100	1163.6	72.0	NONE	.	NONE	.	2.2	2.8	2.8	2.9	2.9	2.9
79303	1.70		.	0.0	100	1095.0	78.8	ALGAE	7.5	NONE	.	1.4	1.4	1.4	1.4	1.6	1.4
79304	1.70	.03	.	0.0	215	2507.7	164.8	EGERIA DENSA	0.1	NONE	.	1.2	1.2	1.2	1.0	1.0	1.0
79305	2.70	BOT	.	0.0	35	493.8	50.5	HYPERICUM	6.1	PISTIA STRATIOTES	2.9	1.0	1.0	1.0	1.0	1.0	1.0
79306	2.20	TOP	.	0.0	120	2219.1	141.3	VALLISNERIA AMERICANA	1.4	NONE	.	2.4	2.3	2.3	2.7	2.7	2.7
79307	1.00	0.2	.	0.0	260	619.7	73.6	NONE	.	NONE	.	1.6	1.6	1.6	1.5	1.5	1.5
79308	1.00	TOP	.	0.0	340	1839.5	148.8	CERATOPHYLLUM DEMERSUM	5.8	POTAMOGETON	0.2	1.1	1.1	1.1	1.2	1.2	1.2
79309	0.45		.	0.5	950	1363.1	135.1	VALLISNERIA AMERICANA	0.2	NONE	.	1.1	1.1	1.1	1.1	1.1	1.1
79310	2.00	TOP	.	0.0	445	838.4	71.1	NAJAS GUADALUPENSIS	0.5	NONE	.	1.4	1.4	1.4	1.4	1.4	1.4
79311	1.00	TOP	.	0.0	370	1861.2	208.9	NAJAS GUADALUPENSIS	2.9	NONE	.	2.5	2.5	2.6	2.1	2.1	2.1
79312	.		.	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
79313	2.50	BOT	.	.	.	645.2	55.2	NONE	.	NONE	.	1.4	1.4	1.4	1.6	1.9	2.2
79314	1.10	TOP	.	.	.	611.5	53.1	CERATOPHYLLUM DEMERSUM	3.1	NONE	.	1.1	1.1	1.1	1.1	1.1	1.1
79315	0.95		.	.	.	1440.5	122.2	CERATOPHYLLUM DEMERSUM	3.3	VALLISNERIA AMERICANA	0.1	1.1	1.1	1.1	1.4	1.4	1.4
79316	1.70	TOP	.	.	.	4008.9	417.8	EGERIA DENSA	0.3	NONE	.	1.8	1.8	1.8	2.1	2.1	2.1
79317	2.60	BOT	.	.	.	503.2	60.3	MYRIOPH SPICATUM	13.2	PISTIA STRATIOTES	1.7	1.0	1.0	.	1.0	1.0	.
79318	0.60	TOP	.	.	.	801.6	72.2	EGERIA DENSA	2.7	NONE	.	1.5	2.5	2.8	2.4	2.8	2.8
79319	0.90	.88	.	.	.	1166.9	124.8	CERATOPHYLLUM DEMERSUM	1.0	VALLISNERIA AMERICANA	0.3	1.7	1.7	1.8	1.8	1.8	1.8
79320	2.80	TOP	.	.	.	863.6	4.5	NAJAS GUADALUPENSIS	1.2	CERATOPHYLLUM DEMERSUM	0.7	1.5	1.6	1.6	1.6	1.6	1.6
79321	0.50	TOP	.	.	.	443.7	67.3	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79322	0.80	TOP	.	.	.	2461.1	248.3	NONE	.	NONE	.	1.3	1.4	1.4	1.5	1.5	1.5
79323	1.60		28.5	0.0	250	1144.1	109.5	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79324	1.50	TOP	24.5	0.2	195	5164.8	474.1	EGERIA DENSA	9.0	NONE	.	1.2	1.2	1.2	1.6	1.8	1.6
79325	2.50	BOT	29.0	0.0	65	466.0	37.3	HYPERICUM	0.4	CERATOPHYLLUM DEMERSUM	0.2	1.0	1.0	1.0	1.0	1.0	1.0
79326	2.40	.05	21.5	0.2	290	2319.0	217.4	VALLISNERIA AMERICANA	1.8	NONE	.	1.3	1.3	1.4	1.9	1.8	1.8
79327	1.10	TOP	32.0	0.0	330	1551.2	127.1	CERATOPHYLLUM DEMERSUM	0.4	NONE	.	2.5	2.6	2.4	2.0	2.0	2.0
79328	1.10	BEL	29.0	0.0	240	475.5	58.0	NONE	.	NONE	.	1.2	1.2	1.2	1.2	1.2	1.2
79329	1.00	TOP	31.0	1.5	2650	1749.5	207.0	MYRIOPH SPICATUM	2.3	VALLISNERIA AMERICANA	0.3	1.4	1.4	1.4	1.4	1.4	1.4
79330	2.50	TOP	30.2	0.0	155	765.8	83.1	NONE	.	NONE	.	.	.	.	.	.	.
79331	0.80		30.3	0.0	132	421.5	35.0	ALGAE	4.3	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79332	1.20	TOP	28.5	0.0	327	1262.5	131.9	NONE	.	NONE	.	.	.	.	.	.	.
79333	0.50	TOP	27.5	0.0	335	.	.	NONE	.	NONE	.	1.0	1.0	1.4	1.0	1.0	1.4
79334	1.40	TOP	29.5	0.0	380	2380.9	230.5	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79335	1.50	TOP	.	.	.	598.5	70.0	NONE	.	NONE	.	.	.	.	.	.	.
79336	1.00	TOP	.	0.5	1100	1645.3	159.1	CERATOPHYLLUM DEMERSUM	1.2	POTAMOGETON	0.9	2.5	2.4	2.5	1.8	1.8	1.8
79337	2.50	TOP	.	0.3	315	831.1	98.6	NONE	.	NONE	.	1.2	1.2	.	1.0	1.0	.
79338	2.70	BOT	.	.	.	185.9	19.2	MYRIOPH SPICATUM	38.1	CERATOPHYLLUM DEMERSUM	0.4	.	.	.	.	.	.
79339	1.50	TOP	.	.	.	4468.7	490.4	EGERIA DENSA	0.7	NONE	.	1.4	1.4	1.4	1.5	1.5	1.5
79340	1.60	.15	.	0.3	320	1227.7	121.6	NONE	.	NONE	.	1.8	2.2	2.5	1.8	1.8	2.0

COLL_NO	DEPTH	MAT_DPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	PLNT_SP2	SP2_DWGT	PLNT_SP3	SP3_DWGT	LDMG_TOP	LDMG_MID	LDMG_BOT	SDMG_TOP	SDMG_MID	SDMG_BOT
79341	0.70	TOP	.	1.0	1900	426.1	60.0	ALGAE	6.9	MYRIOPH SPICATUM	0.1	2.0	2.1	.	1.4	1.4	.
79342	1.50		.	.	.	586.1	83.0	NONE	.	NONE	.	.	.	.	.	.	.
79343	1.00		.	.	.	817.7	58.4	NONE	.	NONE	.	.	.	.	.	.	.
79344	0.50	TOP	.	.	.	902.6	71.5	NONE	.	NONE	.	.	.	.	.	.	.
79345	2.80	TOP	28.5	0.0	590	2390.4	313.8	NONE	.	NONE	.	1.8	2.0	2.1	2.0	2.0	2.0
79346	0.60	TOP	28.5	0.0	630	505.3	64.3	NONE	.	NONE	.	2.1	2.1	2.5	2.1	2.2	2.2
79347	1.20	TOP	30.0	0.0	800	676.8	117.1	NONE	.	NONE	.	1.5	2.0	2.0	1.9	2.6	1.7
79348	0.55		29.0	0.0	325	711.5	79.4	NONE	.	NONE	.	1.2	1.4	1.2	1.2	1.2	1.2
79349	1.20	TOP	31.0	0.0	370	3280.0	377.4	NAJAS GUADALUPENSIS	2.7	NONE	.	2.1	2.1	2.1	1.0	1.1	1.0
79350	0.90	TOP	30.0	1.5	2900	908.5	69.3	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79351	2.30	TOP	27.0	0.0	435	.	.	NONE	.	NONE	.	1.4	1.2	1.2	1.2	1.1	1.1
79352	1.50	TOP	21.0	0.0	225	2371.1	247.8	NONE	.	NONE	.	1.6	1.6	1.6	1.5	1.5	1.5
79353	1.80	TOP	22.5	0.0	230	1715.2	192.9	SAGITTARIA	0.7	NONE	.	1.3	1.7	.	1.2	1.2	.
79354	.	0.5	28.5	0.0	35	117.8	11.1	MYRIOPH HETEROPHYLLUM	2.2	CERATOPHYLLUM DEMERSUM	0.6	1.4	1.3	.	1.0	1.0	.
79355	2.50	TOP	26.0	0.0	100	1801.9	137.5	NONE	.	NONE	.	2.3	2.2	1.9	1.0	1.2	1.0
79356	1.00		28.5	0.0	100	624.2	39.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79357	0.10	TOP	28.0	0.0	340	943.5	77.5	NONE	.	NONE	.	2.4	2.2	.	2.4	1.8	.
79358	0.85		.	0.0	400	664.5	85.5	NONE	.	NONE	.	.	.	.	.	.	.
79359	1.00	TOP	.	0.0	195	668.5	98.5	NONE	.	NONE	.	1.7	1.9	2.0	2.1	2.0	2.2
79360	0.30		.	.	225	804.9	68.8	NAJAS GUADALUPENSIS	0.7	NONE	.	1.4	1.4	1.4	1.4	1.4	1.4
79361	1.50		.	.	230	2954.4	349.4	NONE	.	NONE	.	1.9	2.1	2.1	1.3	1.3	1.3
79362	3.30		.	0.0	402	1526.7	161.7	NONE	.	NONE	.	1.0	1.1	1.1	1.1	1.1	1.1
79363	1.80	TOP	.	.	.	5422.0	532.6	NONE	.	NONE	.	.	.	.	.	.	.
79364	1.70		20.0	0.0	155	2555.8	341.2	NONE	.	NONE	.	1.7	1.9	1.8	1.8	1.5	1.3
79365	2.70		.	0.0	25	280.1	31.3	CERATOPHYLLUM DEMERSUM	1.6	BACOPA	0.1	1.4	1.4	.	1.0	1.0	.
79366	1.90		.	.	.	2096.1	190.8	SAGITTARIA	11.6	EGERIA DENSA	2.2	1.8	2.8	.	2.3	2.4	.
79367	.	TOP	.	.	.	1052.2	88.8	CERATOPHYLLUM DEMERSUM	1.7	NONE	.	1.7	2.3	2.0	1.8	1.7	1.4
79368	0.70	BEL	.	.	.	980.8	119.3	NONE	.	NONE	.	1.5	1.5	1.5	1.0	1.2	1.3
79369	0.40	TOP	.	1.0	1500	790.5	104.9	NONE	.	NONE	.	.	.	.	.	.	.
79370	1.70		.	0.0	50	1758.6	143.2	NONE	.	NONE	.	1.9	2.2	.	1.9	1.9	.
79371	1.20		.	.	.	401.1	30.8	CERATOPHYLLUM DEMERSUM	3.1	NONE	.	.	.	.	.	.	.
79372	1.20		26.0	0.0	550	1044.1	76.5	NAJAS GUADALUPENSIS	0.3	NONE	.	2.2	2.2	2.4	2.0	2.1	2.2
79373	1.50		31.0	0.0	240	772.0	72.0	NONE	.	NONE	.	1.5	2.0	2.0	1.5	1.6	1.6
79374	0.40		32.0	0.0	300	689.9	67.8	NONE	.	NONE	.	.	.	.	.	.	.
79375	1.50		32.0	0.0	370	1276.7	148.7	NONE	.	NONE	.	1.4	1.7	1.8	1.6	1.7	2.3
79376	.		17.5	0.0	345	701.5	65.2	NONE	.	NONE	.	1.0	1.0	1.0	1.5	2.0	1.5
79377	0.20		21.0	0.0	500	846.5	53.6	NONE	.	NONE	.	1.5	1.7	1.6	1.6	1.8	1.8
79378	2.60		22.0	0.0	115	1030.8	32.9	NONE	.	NONE	.	1.0	1.4	1.2	1.3	1.4	1.3
79379	1.20	0.3	23.0	0.0	160	755.1	59.6	NONE	.	NONE	.	1.4	1.5	1.6	1.5	1.6	1.6
79380	0.80	TOP	24.5	0.0	240	935.4	102.4	NONE	.	NONE	.	.	.	.	.	.	.
79381	0.50		21.0	0.0	270	778.5	83.0	NONE	.	NONE	.	.	.	.	.	.	.
79382	4.00		.	0.0	403	.	.	NONE	.	NONE	.	.	.	.	.	.	.
79383	2.50		23.0	0.0	80	1315.5	98.7	NONE	.	NONE	.	2.1	2.1	1.6	1.0	1.0	1.0
79384	1.00	TOP	22.0	0.0	80	.	.	NONE	.	NONE	.	.	.	.	.	.	.
79385	0.40	BEL	19.5	0.0	230	783.0	48.7	NONE	.	NONE	.	1.3	1.4	1.4	1.3	1.4	1.3
79386	1.40	BOT	21.0	0.0	225	90.6	8.7	NONE	.	NONE	.	.	.	.	.	.	.
79387	1.40	TOP	.	.	.	2148.4	279.1	NONE	.	NONE	.	.	.	.	.	.	.
79388	2.40	2.1	19.0	0.0	22	232.8	22.9	CERATOPHYLLUM DEMERSUM	0.9	NONE	.	.	.	.	.	.	.

COLL_NO	DEPTH	MAT_DEPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	FLNT_SP2	SP2_DWGT	FLNT_SP3	SP3_DWGT	LDMG_TOP	LDMG_MID	LDMG_BOT	SDMG_TOP	SDMG_MID	SDMG_BOT
79389	0.80		16.5	0.0	57	627.8	72.0	NONE	.	NONE	.	1.0	1.1	1.0	1.1	1.2	1.1
79390	2.00	BOT	17.0	0.0	90	668.4	95.8	NONE	.	NONE	.	.	.	.	.	.	.
79391	7.60	.15	19.0	0.0	65	93.1	68.0	NONE	.	NONE	.	.	.	.	.	.	.
79392	.		.	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
79393	1.10	.07	24.0	0.0	195	219.6	43.0	NONE	.	NONE	.	.	.	.	.	.	.
79394	1.00		20.5	0.2	360	366.4	30.8	POTAMOGETON	7.7	CERATOPHYLLUM DEMERSUM	7.2	1.5	1.9	.	1.4	1.3	.
79395	1.00	TOP	23.5	0.2	550	1232.2	110.8	NONE	.	NONE	.	1.1	1.6	1.7	1.2	1.1	1.1
79396	1.40		22.0	0.0	250	1218.5	103.6	UTRICULARIA	0.1	NONE	.	1.4	1.6	1.6	1.2	1.1	1.0
79397	0.60	TOP	23.5	0.0	325	2459.7	181.9	NAJAS GUADALUPENSIS	3.6	NONE	.	2.3	2.4	2.4	2.0	2.2	1.9
79398	1.30		22.5	0.0	350	5599.1	443.7	NAJAS GUADALUPENSIS	0.5	UTRICULARIA	0.3	2.7	3.1	3.0	1.4	1.2	1.1
79399	.	TOP	17.0	0.0	120	1645.0	141.2	NONE	.	NONE	.	1.6	1.6	1.0	1.1	1.1	1.0
79400	1.00	TOP	17.0	0.0	68	636.2	46.5	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79401	2.00	0.3	17.5	0.0	355	806.5	66.4	CERATOPHYLLUM DEMERSUM	2.9	NONE	.	1.3	1.6	1.7	1.5	1.4	1.2
79402	1.00	TOP	18.5	0.0	175	607.3	59.0	NONE	.	NONE	.	2.2	1.9	1.8	1.8	1.4	1.4
79403	1.50	0.7	.	0.0	215	344.6	28.8	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
79404	2.70	1.0	15.5	0.0	23	439.0	46.4	BACOPA	0.1	NONE	.	1.6	1.7	2.0	1.0	1.1	2.0
79405	1.20	0.5	23.0	0.0	197	461.6	56.9	NONE	.	NONE	.	1.2	1.1	1.1	1.1	1.0	1.0
79406	0.90	TOP	23.5	0.5	1000	680.7	50.7	MYRIOPH SPICATUM	0.4	CERATOPHYLLUM DEMERSUM	0.2	2.9	3.9	3.2	2.5	2.9	2.7
79407	.		21.5	0.1	470	463.4	38.5	NONE	.	NONE	.	2.0	2.0	2.6	1.5	1.5	1.8
79408	1.50	TOP	19.0	0.20	260	857.3	87.0	NAJAS GUADALUPENSIS	0.1	NONE	.	1.7	1.7	1.7	1.0	1.0	1.0
79409	0.60	0.1	20.0	0.00	320	1947.0	153.5	NAJAS GUADALUPENSIS	5.7	NONE	.	2.2	2.4	2.4	1.9	1.8	1.7
79410	1.40	0.5	20.0	0.00	330	999.8	88.4	NAJAS GUADALUPENSIS	0.6	NONE	.	1.4	1.7	.	1.3	1.2	.
79411	2.80	TOP	18.5	0.00	173	1376.9	110.1	NONE	.	NONE	.	1.7	2.5	2.5	1.2	1.7	1.2
79412	3.20	2.0	19.5	0.30	550	177.4	12.6	NONE	.	NONE	.	1.1	1.2	1.3	1.1	1.2	1.2
79413	0.50	TOP	24.5	0.50	1000	917.2	76.9	MYRIOPH SPICATUM	0.2	NONE	.	.	.	.	.	.	.
80201	2.40	TOP	15.5	0.00	150	1533.0	129.8	NONE	.	NONE	.	2.1	2.3	.	1.7	1.7	.
80202	1.00	TOP	13.0	0.00	65	631.1	45.3	NONE	.	NONE	.	1.2	1.3	1.3	1.2	1.2	1.2
80203	1.00	TOP	14.0	0.00	240	1234.0	77.7	CERATOPHYLLUM DEMERSUM	12.9	NONE	.	1.4	1.8	1.5	1.1	1.2	1.1
80204	1.50	0.3	19.5	0.00	205	1191.0	56.7	NONE	.	NONE	.	1.3	1.9	.	1.7	1.7	.
80205	2.20	BOT	11.5	0.00	20	139.5	15.0	MYRIOPH HETEROPHYLLUM	5.1	ALGAE	2.2	.	.	.	.	.	.
80206	1.00	0.5	17.5	0.00	210	1341.6	64.6	CERATOPHYLLUM DEMERSUM	2.1	VALLISNERIA AMERICANA	0.3	1.3	1.4	1.4	1.3	1.4	1.4
80207	0.40	TOP	20.5	0.40	880	289.0	25.9	NONE	.	NONE	.	2.1	1.9	.	2.0	1.9	.
80208	1.00	0.3	.	0.00	240	632.9	59.0	NONE	.	NONE	.	.	.	.	.	.	.
80209	0.90	0.2	22.5	0.20	500	735.7	72.4	NONE	.	NONE	.	.	.	.	.	.	.
80210	1.40	0.1	21.0	0.00	260	1336.7	114.4	NONE	.	NONE	.	1.7	2.4	2.2	1.7	1.8	1.7
80211	0.50	0.3	21.5	0.00	400	1396.0	79.9	NONE	.	NONE	.	.	.	.	.	.	.
80212	1.30	0.4	22.5	0.00	400	995.2	90.8	NAJAS GUADALUPENSIS	0.8	NONE	.	2.4	2.2	.	1.8	1.9	.
80213	3.50	TOP	19.5	0.00	600	534.0	49.9	NONE	.	NONE	.	1.3	1.4	.	1.2	1.2	.
80214	0.70	TOP	12.5	0.00	217	775.4	59.6	CERATOPHYLLUM DEMERSUM	1.4	NONE	.	1.6	2.2	.	1.7	1.6	.
80215	0.60	0.1	19.0	0.50	1050	77.9	8.7	NONE	.	NONE	.	.	.	.	.	.	.
80216	1.20	0.5	21.2	0.10	192	724.6	76.2	NONE	.	NONE	.	.	.	.	.	.	.
80217	2.60	TOP	12.7	0.00	125	1379.6	105.8	NONE	.	NONE	.	1.8	1.7	.	1.2	1.2	.
80218	1.00	TOP	14.0	0.00	62	897.6	50.7	NONE	.	NONE	.	.	.	.	.	.	.
80219	2.70	BOT	11.0	0.00	23	421.6	45.8	NONE	.	NONE	.	.	.	.	.	.	.
80220	1.60	0.1	18.7	0.00	205	2729.3	153.7	NONE	.	NONE	.	.	.	.	.	.	.
80221	0.80	0.5	15.3	0.00	180	644.7	45.9	NONE	.	NONE	.	.	.	.	.	.	.
80222	1.00	0.3	21.0	0.00	550	302.0	30.3	NONE	.	NONE	.	1.2	1.2	1.3	1.4	1.4	1.4
80223	1.60	TOP	20.0	0.00	250	494.5	42.0	NONE	.	NONE	.	1.2	1.2	1.0	1.1	1.1	1.0
80224	0.50		20.0	0.00	380	750.6	63.2	NONE	.	NONE	.	.	.	.	.	.	.
80225	1.40	0.2	22.0	0.00	410	386.5	36.3	NAJAS GUADALUPENSIS	0.7	NONE	.	1.4	1.5	.	1.2	1.2	.
80226	3.40	BEL	19.7	0.40	565	1624.0	99.5	ALGAE	1.1	NONE	.	[illegible]	[illegible]	[illegible]	1.4	1.5	1.0

COLL_NO	DEPTH	MAT_DPTH	H2OTEMP	SALINITY	CONDUCT	WET_WGT	DRY_WGT	PLNT_SP2	SP2_DWGT	PLNT_SP3	SP3_DWGT	LDMG_TOP	LDMG_MID	LDMG_BOT	SDMG_TOP	SDMG_MID	SDMG_BOT
80227	2.80	BEL	17.0	0.00	102	469.6	35.4	NONE	.	NONE	.	2.0	1.6	.	1.3	1.5	.
80228	1.00	BEL	21.0	0.00	70	713.6	57.4	NONE	.	NONE	.	1.8	2.0	1.8	1.2	1.2	1.2
80229	1.70	BEL	20.5	0.20	295	99.5	6.0	CERATOPHYLLUM DEMERSUM	0.8	NONE	.	2.0	2.7	.	1.3	1.9	.
80230	0.30	BOT	22.5	0.50	1075	227.1	28.9	NONE	.	NONE	.	1.0	1.0	1.0	1.2	1.2	1.2
80231	1.30	0.6	23.2	0.00	225	398.2	50.2	NONE	.	NONE	.	1.1	1.1	1.0	1.0	1.0	1.0
80232	2.40	BEL	19.0	0.00	30	67.3	4.3	MYRIOPH SPICATUM	5.5	BACOPA	0.4	1.0	1.0	.	1.0	1.0	.
80233	1.70	TOP	20.5	0.00	187	4001.3	325.0	NONE	.	NONE	.	1.0	1.4	1.3	1.1	1.2	1.2
80234	0.90	BOT	22.0	0.00	100	100.9	7.5	NONE	.	NONE	.	1.8	1.2	1.2	1.5	1.0	1.2
80235	0.90	0.1	25.0	0.00	560	211.4	16.0	NONE	.	NONE	.	1.2	1.4	1.6	1.1	1.3	1.6
80236	0.90		24.0	0.00	340	393.3	26.9	LIMNOBIUM SPONGIA	1.0	NAJAS GUADALUPENSIS	0.4	2.1	2.3	2.3	1.5	1.6	1.7
80237	0.30	TOP	23.0	0.00	400	608.2	81.3	NONE	.	NONE	.	1.9	1.9	2.4	2.0	2.1	2.4
80238	1.30	0.1	27.0	0.00	450	170.6	11.1	NONE	.	NONE	.	1.1	1.2	1.0	1.1	1.1	1.0
80239	3.60	0.1	26.2	0.30	725	104.4	10.6	NONE	.	NONE	.	1.1	1.2	1.7	1.2	1.2	1.7
80240	1.70	BEL	21.7	0.10	325	163.7	11.0	CERATOPHYLLUM DEMERSUM	1.2	NONE	.	2.2	3.0	2.5	1.8	1.8	2.0
80241	2.50	BEL	2.0	0.00	70	502.9	38.7	NONE	.	NONE	.	1.2	1.2	1.0	1.1	1.1	1.0
80242	1.10	TOP	20.0	0.00	70	464.2	22.1	NONE	.	NONE	.	.	.	.	.	.	.
80243	0.80	0.4	22.0	0.00	200	893.1	139.1	NONE	.	NONE	.	1.5	1.5	2.0	1.0	1.0	1.4
80244	.		.	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
80245	2.90	BOT	19.0	0.00	25	41.4	4.5	BACOPA	0.1	CERATOPHYLLUM DEMERSUM	0.1	1.0	1.0	1.0	1.0	1.0	1.0
80246	2.00	TOP	20.0	0.00	190	4579.4	318.3	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
80247	1.10	BOT	19.0	0.00	135	.	.	NONE	.	NONE	.	.	.	.	.	.	.
80248	0.70	BEL	23.0	0.00	500	478.0	41.2	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
80249	1.20	BEL	23.5	0.00	250	701.0	50.5	NONE	.	NONE	.	1.0	1.2	1.2	1.0	1.0	1.0
80250	0.80	TOP	22.0	0.00	300	910.5	69.0	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
80251	1.10	.04	24.5	0.00	410	1667.7	144.8	NAJAS GUADALUPENSIS	0.4	BACOPA	0.1	1.0	1.2	1.2	1.0	1.0	1.0
80252	2.60	0.2	23.0	0.00	165	1084.1	76.8	NONE	.	NONE	.	1.2	1.2	.	1.0	1.0	.
80253	1.70	0.5	23.5	0.00	335	398.1	38.3	NONE	.	NONE	.	1.9	1.9	2.5	1.4	1.4	2.4
80254	1.90	TOP	21.0	0.00	215	7011.3	633.1	NONE	.	NONE	.	1.1	1.3	1.3	1.1	1.1	1.1
80255	1.90	TOP	21.0	0.00	215	10291.0	708.6	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
80256	1.10	0.2	25.0	0.00	554	553.5	69.5	NONE	.	NONE	.	2.1	2.2	.	2.1	2.1	.
80257	0.60	TOP	29.0	0.00	350	1466.0	142.2	NAJAS GUADALUPENSIS	0.3	NONE	.	1.7	1.6	.	1.5	1.5	.
80258	1.90	BEL	27.5	0.00	410	473.0	57.1	NONE	.	NONE	.	1.2	1.5	.	1.0	1.2	.
80259	2.50	BEL	27.7	0.00	555	1639.4	140.0	NONE	.	NONE	.	1.2	1.3	.	1.0	1.0	.
80260	1.70	BEL	20.5	0.00	237	4803.5	585.3	EGERIA DENSA	7.9	NONE	.	1.1	1.1	1.0	1.0	1.0	1.0
80261	1.50	TOP	28.7	0.20	720	562.5	59.2	NONE	.	NONE	.	1.0	1.0	1.0	1.0	1.0	1.0
80262	0.70	BEL	31.0	0.00	350	1831.6	193.7	NONE	.	NONE	.	1.6	1.8	.	1.2	1.2	.
80263	1.80	BEL	29.5	0.30	410	428.8	359.6	NONE	.	NONE	.	1.0	1.0	.	1.0	1.0	.
80264	2.50	TOP	27.2	0.00	162	1267.2	141.0	NONE	.	NONE	.	1.0	1.1	.	1.0	1.0	.
80265	1.60	TOP	20.7	0.00	230	3966.0	632.9	NONE	.	NONE	.	1.0	1.2	.	1.0	1.2	.
80266	1.30	TOP	23.0	0.00	295	320.7	39.6	NONE	.	NONE	.	1.0	1.4	1.	1.2	1.4	1.5
80267	1.20	BEL	27.4	0.15	382	1360.6	268.9	NONE	.	NONE	.	1.2	1.3	1.	1.0	1.0	1.2
80268	2.50	TOP	23.5	0.00	145	1342.8	107.5	NONE	.	NONE	.	.	.	.	.	.	.
80269	0.35	BOT	18.0	0.30	590	373.4	28.4	NONE	.	NONE	.	1.8	2.1	2.	1.8	2.2	2.5
80270	0.55	BOT	20.0	0.20	550	.	32.9	NONE	.	NONE	.	.	.	.	.	.	.
80271	0.65	0.5	20.0	0.20	550	316.5	33.1	NONE	.	NONE	.	3.0	2.7	.	3.0	2.6	.
80272	0.40	0.3	.	.	.	369.5	47.0	NONE	.	NONE	.	1.9	2.0	2.2	1.1	1.2	1.3
80273	2.90	TOP	.	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.
80274	1.70	0.2	30.0	0.00	302	87.9	8.3	NONE	.	NONE	.	1.5	1.5	1.5	1.0	1.0	1.0
80275	2.60	TOP	31.0	0.00	95	.	.	NONE	.	NONE	.	.	.	.	.	.	.
80276	6.00		27.0	0.00	150	.	.	NONE	.	NONE	.	.	.	.	.	.	.
80277	.		.	.	.	.	.	NONE	.	NONE	.	.	.	.	.	.	.

APPENDIX F: QUANTITATIVE HYDRILLA RESULTS FOR LAKE JACKSON, LEON COUNTY, FLORIDA

COLL_NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
78245	06-DEC-1978	WEST SIDE BY US 27	8	0	1	464.2	11.2
78245	06-DEC-1978	WEST SIDE BY US 27			2	413.4	11.3
78245	06-DEC-1978	WEST SIDE BY US 27			3	380.2	13.3
78245	06-DEC-1978	WEST SIDE BY US 27			4	284.2	7.7
78245	06-DEC-1978	WEST SIDE BY US 27			5	.	.
79260	10-JAN-1979	WEST SIDE BY US 27	27	1	1	59.2	1.3
79260	10-JAN-1979	WEST SIDE BY US 27			2	65.7	2.2
79260	10-JAN-1979	WEST SIDE BY US 27			3	39.4	1.2
79260	10-JAN-1979	WEST SIDE BY US 27			4	37.2	1.1
79260	10-JAN-1979	WEST SIDE BY US 27			5	49.9	1.5
79272	07-FEB-1979	WEST SIDE BY US 27	79	24	1	18.5	1.0
79272	07-FEB-1979	WEST SIDE BY US 27			2	37.2	1.8
79272	07-FEB-1979	WEST SIDE BY US 27			3	86.0	4.8
79272	07-FEB-1979	WEST SIDE BY US 27			4	42.6	2.5
79272	07-FEB-1979	WEST SIDE BY US 27			5	51.8	2.4
79281	07-MAR-1979	WEST SIDE BY US 27	12	0	1	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			2	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			3	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			4	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			5	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			6	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			7	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			8	.	.
79281	07-MAR-1979	WEST SIDE BY US 27			9	.	.
79305	09-MAY-1979	WEST SIDE BY US 27	25	36	1	48.1	5.0
79305	09-MAY-1979	WEST SIDE BY US 27			2	60.0	5.7
79305	09-MAY-1979	WEST SIDE BY US 27			3	110.1	8.5
79305	09-MAY-1979	WEST SIDE BY US 27			4	117.7	13.9
79305	09-MAY-1979	WEST SIDE BY US 27			5	157.9	17.4
79317	06-JUN-1979	WEST SIDE BY US 27	7	26	1	121.1	11.0
79317	06-JUN-1979	WEST SIDE BY US 27			2	64.5	6.4
79317	06-JUN-1979	WEST SIDE BY US 27			3	151.2	20.9
79317	06-JUN-1979	WEST SIDE BY US 27			4	86.0	12.0
79317	06-JUN-1979	WEST SIDE BY US 27			5	80.4	10.0
79325	10-JUL-1979	WEST SIDE BY US 27	14	32	1	116.0	8.9
79325	10-JUL-1979	WEST SIDE BY US 27			2	90.8	7.1
79325	10-JUL-1979	WEST SIDE BY US 27			3	103.2	7.7
79325	10-JUL-1979	WEST SIDE BY US 27			4	94.6	8.2
79325	10-JUL-1979	WEST SIDE BY US 27			5	61.4	5.4
79338	08-AUG-1979	WEST SIDE BY US 27	20	29	1	0.7	0.2
79338	08-AUG-1979	WEST SIDE BY US 27			2	41.9	4.3
79338	08-AUG-1979	WEST SIDE BY US 27			3	19.3	1.5
79338	08-AUG-1979	WEST SIDE BY US 27			4	62.2	6.6
79338	08-AUG-1979	WEST SIDE BY US 27			5	61.8	6.6
79354	07-SEP-1979	WEST SIDE BY US 27	38	10	1	10.5	0.9
79354	07-SEP-1979	WEST SIDE BY US 27			2	37.6	3.3
79354	07-SEP-1979	WEST SIDE BY US 27			3	5.7	0.6
79354	07-SEP-1979	WEST SIDE BY US 27			4	37.9	3.9
79354	07-SEP-1979	WEST SIDE BY US 27			5	26.1	[illegible]

COLL_NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79365	09-OCT-1979	WEST SIDE BY US 27	6	5	1	59.6	6.2
79365	09-OCT-1979	WEST SIDE BY US 27			2	95.7	11.1
79365	09-OCT-1979	WEST SIDE BY US 27			3	34.9	3.7
79365	09-OCT-1979	WEST SIDE BY US 27			4	76.6	8.7
79365	09-OCT-1979	WEST SIDE BY US 27			5	13.3	1.6
79388	08-NOV-1979	WEST SIDE BY US 27	16	8	1	34.8	3.5
79388	08-NOV-1979	WEST SIDE BY US 27			2	53.2	5.7
79388	08-NOV-1979	WEST SIDE BY US 27			3	40.2	3.8
79388	08-NOV-1979	WEST SIDE BY US 27			4	15.7	1.4
79388	08-NOV-1979	WEST SIDE BY US 27			5	88.9	8.5
79404	12-DEC-1979	WEST SIDE BY US 27	319	41	1	97.0	9.8
79404	12-DEC-1979	WEST SIDE BY US 27			2	95.0	10.0
79404	12-DEC-1979	WEST SIDE BY US 27			3	107.0	11.3
79404	12-DEC-1979	WEST SIDE BY US 27			4	69.7	7.4
79404	12-DEC-1979	WEST SIDE BY US 27			5	70.3	7.9
80205	09-JAN-1980	WEST SIDE BY US 27	80	48	1	45.7	6.4
80205	09-JAN-1980	WEST SIDE BY US 27			2	48.7	5.0
80205	09-JAN-1980	WEST SIDE BY US 27			3	37.0	3.1
80205	09-JAN-1980	WEST SIDE BY US 27			4	8.1	0.5
80205	09-JAN-1980	WEST SIDE BY US 27			5	.	.
80219	12-FEB-1980	WEST SIDE BY US 27	542	87	1	109.1	12.7
80219	12-FEB-1980	WEST SIDE BY US 27			2	80.6	10.9
80219	12-FEB-1980	WEST SIDE BY US 27			3	73.6	6.2
80219	12-FEB-1980	WEST SIDE BY US 27			4	64.3	6.3
80219	12-FEB-1980	WEST SIDE BY US 27			5	94.0	9.7
80232	13-MAR-1980	WEST SIDE BY US 27	29	33	1	23.3	2.5
80232	13-MAR-1980	WEST SIDE BY US 27			2	10.0	0.7
80232	13-MAR-1980	WEST SIDE BY US 27			3	8.2	0.2
80232	13-MAR-1980	WEST SIDE BY US 27			4	16.2	0.6
80232	13-MAR-1980	WEST SIDE BY US 27			5	9.6	0.3
80245	08-APR-1980	WEST SIDE BY US 27	21	4	1	5.2	0.2
80245	08-APR-1980	WEST SIDE BY US 27			2	31.0	0.5
80245	08-APR-1980	WEST SIDE BY US 27			3	1.4	0.1
80245	08-APR-1980	WEST SIDE BY US 27			4	1.1	0.1
80245	08-APR-1980	WEST SIDE BY US 27			5	2.7	3.6

APPENDIX G: QUANTITATIVE HYDRILLA RESULTS FOR THE WACISSA RIVER, JEFFERSON COUNTY, FLORIDA

COLL_NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
78244	06-DEC-1979	SWIM AREA AT HEAD SPRINGS	2	0	1	385.2	19.3
78244	06-DEC-1979	SWIM AREA AT HEAD SPRINGS			2	350.7	8.8
78244	06-DEC-1979	SWIM AREA AT HEAD SPRINGS			3	386.7	21.7
78244	06-DEC-1979	SWIM AREA AT HEAD SPRINGS			4	428.4	14.6
79259	10-JAN-1979	SWIM AREA AT HEAD SPRINGS	3	0	1	336.8	19.6
79259	10-JAN-1979	SWIM AREA AT HEAD SPRINGS			2	291.1	18.0
79259	10-JAN-1979	SWIM AREA AT HEAD SPRINGS			3	288.6	17.6
79259	10-JAN-1979	SWIM AREA AT HEAD SPRINGS			4	248.6	13.2
79259	10-JAN-1979	SWIM AREA AT HEAD SPRINGS			5	341.5	18.5
79271	07-FEB-1979	400 METERS BELOW SWIM AREA	2	250	1	899.4	57.4
79271	07-FEB-1979	400 METERS BELOW SWIM AREA			2	835.3	64.8
79271	07-FEB-1979	400 METERS BELOW SWIM AREA			3	866.2	72.3
79271	07-FEB-1979	400 METERS BELOW SWIM AREA			4	783.0	73.9
79271	07-FEB-1979	400 METERS BELOW SWIM AREA			5	974.3	80.5
79280	07-MAR-1979	400 METERS BELOW SWIM AREA	1	244	1	470.0	30.2
79280	07-MAR-1979	400 METERS BELOW SWIM AREA			2	464.3	30.6
79280	07-MAR-1979	400 METERS BELOW SWIM AREA			3	344.2	26.1
79280	07-MAR-1979	400 METERS BELOW SWIM AREA			4	316.2	22.1
79280	07-MAR-1979	400 METERS BELOW SWIM AREA			5	448.5	33.2
79291	10-APR-1979	400 METERS BELOW SWIM AREA	6	510	1	565.1	34.1
79291	10-APR-1979	400 METERS BELOW SWIM AREA			2	642.8	49.3
79291	10-APR-1979	400 METERS BELOW SWIM AREA			3	683.9	47.8
79291	10-APR-1979	400 METERS BELOW SWIM AREA			4	611.6	39.8
79291	10-APR-1979	400 METERS BELOW SWIM AREA			5	655.2	39.8
79304	09-MAY-1979	400 METERS BELOW SWIM AREA	6	478	1	444.7	31.4
79304	09-MAY-1979	400 METERS BELOW SWIM AREA			2	464.6	30.4
79304	09-MAY-1979	400 METERS BELOW SWIM AREA			3	332.7	24.2
79304	09-MAY-1979	400 METERS BELOW SWIM AREA			4	623.4	37.0
79304	09-MAY-1979	400 METERS BELOW SWIM AREA			5	642.3	41.8
79316	06-JUN-1979	400 METERS BELOW SWIM AREA	3	991	1	739.2	84.9
79316	06-JUN-1979	400 METERS BELOW SWIM AREA			2	705.6	70.1
79316	06-JUN-1979	400 METERS BELOW SWIM AREA			3	910.9	76.8
79316	06-JUN-1979	400 METERS BELOW SWIM AREA			4	811.8	90.1
79316	06-JUN-1979	400 METERS BELOW SWIM AREA			5	841.4	95.9
79324	10-JUL-1979	400 METERS BELOW SWIM AREA	50	577	1	1115.6	120.8
79324	10-JUL-1979	400 METERS BELOW SWIM AREA			2	1172.6	94.7
79324	10-JUL-1979	400 METERS BELOW SWIM AREA			3	1119.4	85.0
79324	10-JUL-1979	400 METERS BELOW SWIM AREA			4	864.9	84.4
79324	10-JUL-1979	400 METERS BELOW SWIM AREA			5	892.3	89.2
79339	08-AUG-1979	400 METERS BELOW SWIM AREA	35	552	1	722.1	84.8
79339	08-AUG-1979	400 METERS BELOW SWIM AREA			2	899.7	96.2
79339	08-AUG-1979	400 METERS BELOW SWIM AREA			3	904.0	101.6
79339	08-AUG-1979	400 METERS BELOW SWIM AREA			4	968.1	110.5
79339	08-AUG-1979	400 METERS BELOW SWIM AREA			5	774.8	97.3
79352	06-SEP-1979	400 METERS BELOW SWIM AREA	20	72	1	488.2	51.7
79352	06-SEP-1979	400 METERS BELOW SWIM AREA			2	482.7	47.9
79352	06-SEP-1979	400 METERS BELOW SWIM AREA			3	496.6	57.9
79352	06-SEP-1979	400 METERS BELOW SWIM AREA			4	433.4	40.1
79352	06-SEP-1979	400 METERS BELOW SWIM AREA			5	[illegible]	[illegible]

COLL NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79364	09-OCT-1979	400 METERS BELOW SWIM AREA	12	51	1	390.5	53.3
79364	09-OCT-1979	400 METERS BELOW SWIM AREA			2	614.6	66.6
79364	09-OCT-1979	400 METERS BELOW SWIM AREA			3	433.8	59.8
79364	09-OCT-1979	400 METERS BELOW SWIM AREA			4	673.1	86.7
79364	09-OCT-1979	400 METERS BELOW SWIM AREA			5	443.8	74.8
79386	07-NOV-1979	400 METERS BELOW SWIM AREA	2	337	1	10.5	0.8
79386	07-NOV-1979	400 METERS BELOW SWIM AREA			2	10.8	1.1
79386	07-NOV-1979	400 METERS BELOW SWIM AREA			3	6.1	0.4
79386	07-NOV-1979	400 METERS BELOW SWIM AREA			4	28.6	3.0
79386	07-NOV-1979	400 METERS BELOW SWIM AREA			5	34.6	3.4
79387	07-NOV-1979	420 METERS BELOW SWIM AREA	11	288	1	349.1	47.2
79387	07-NOV-1979	420 METERS BELOW SWIM AREA			2	609.0	61.1
79387	07-NOV-1979	420 METERS BELOW SWIM AREA			3	395.8	59.6
79387	07-NOV-1979	420 METERS BELOW SWIM AREA			4	309.5	44.1
79387	07-NOV-1979	420 METERS BELOW SWIM AREA			5	485.0	67.1
79403	12-DEC-1979	400 METERS BELOW SWIM AREA	4	190	1	49.5	4.0
79403	12-DEC-1979	400 METERS BELOW SWIM AREA			2	69.4	5.0
79403	12-DEC-1979	400 METERS BELOW SWIM AREA			3	32.2	2.6
79403	12-DEC-1979	400 METERS BELOW SWIM AREA			4	111.0	10.6
79403	12-DEC-1979	400 METERS BELOW SWIM AREA			5	82.5	6.6
80204	09-JAN-1980	400 METERS BELOW SWIM AREA	0	212	1	202.7	8.9
80204	09-JAN-1980	400 METERS BELOW SWIM AREA			2	270.1	13.0
80204	09-JAN-1980	400 METERS BELOW SWIM AREA			3	199.1	10.4
80204	09-JAN-1980	400 METERS BELOW SWIM AREA			4	276.9	12.6
80204	09-JAN-1980	400 METERS BELOW SWIM AREA			5	242.2	11.8
80220	12-FEB-1980	400 METERS BELOW SWIM AREA	0	546	1	529.7	31.5
80220	12-FEB-1980	400 METERS BELOW SWIM AREA			2	526.7	31.1
80220	12-FEB-1980	400 METERS BELOW SWIM AREA			3	687.3	29.2
80220	12-FEB-1980	400 METERS BELOW SWIM AREA			4	483.0	33.3
80220	12-FEB-1980	400 METERS BELOW SWIM AREA			5	502.6	28.6
80233	13-MAR-1980	400 METERS BELOW SWIM AREA	1	763	1	777.0	103.0
80233	13-MAR-1980	400 METERS BELOW SWIM AREA			2	725.7	58.6
80233	13-MAR-1980	400 METERS BELOW SWIM AREA			3	735.0	39.7
80233	13-MAR-1980	400 METERS BELOW SWIM AREA			4	796.1	56.2
80233	13-MAR-1980	400 METERS BELOW SWIM AREA			5	967.5	67.4
80246	08-APR-1980	400 METERS BELOW SWIM AREA	2	767	1	1213.6	74.7
80246	08-APR-1980	400 METERS BELOW SWIM AREA			2	911.5	66.3
80246	08-APR-1980	400 METERS BELOW SWIM AREA			3	745.2	60.9
80246	08-APR-1980	400 METERS BELOW SWIM AREA			4	806.7	57.3
80246	08-APR-1980	400 METERS BELOW SWIM AREA			5	902.4	59.1

COLL. NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
80254	07-MAY-1980	400 METERS BELOW SWIM AREA	18	1314	1	1000.7	91.2
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			2	804.2	81.6
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			3	877.5	79.7
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			4	874.1	75.6
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			5	887.0	79.7
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			6	852.5	74.3
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			7	892.0	78.9
80254	07-MAY-1980	400 METERS BELOW SWIM AREA			8	823.3	72.1
80255	07-MAY-1980	400 METERS BELOW SWIM AREA	6	1135	1	1232.4	83.3
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			2	1288.8	88.6
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			3	1461.2	100.5
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			4	1346.6	87.2
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			5	1503.2	99.4
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			6	1356.9	88.5
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			7	1072.1	82.2
80255	07-MAY-1980	400 METERS BELOW SWIM AREA			8	1029.5	78.9
80260	11-JUN-1980	400 METERS BELOW SWIM AREA	101	1279	1	1113.9	116.2
80260	11-JUN-1980	400 METERS BELOW SWIM AREA			2	853.0	110.4
80260	11-JUN-1980	400 METERS BELOW SWIM AREA			3	908.0	123.6
80260	11-JUN-1980	400 METERS BELOW SWIM AREA			4	1069.4	124.4
80260	11-JUN-1980	400 METERS BELOW SWIM AREA			5	859.2	110.7
80265	09-JUL-1980	400 METERS BELOW SWIM AREA	9	888	1	725.2	108.2
80265	09-JUL-1980	400 METERS BELOW SWIM AREA			2	792.6	144.0
80265	09-JUL-1980	400 METERS BELOW SWIM AREA			3	736.2	112.1
80265	09-JUL-1980	400 METERS BELOW SWIM AREA			4	878.4	131.8
80265	09-JUL-1980	400 METERS BELOW SWIM AREA			5	833.6	136.8

APPENDIX H: QUANTITATIVE HYDRILLA RESULTS FOR LAKE LOCHLOOSA, ALACHUA COUNTY, FLORIDA

COLL.NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79269	06-FEB-1979	500 METERS FROM SW CORNER	108	54	1	168.7	14.0
79269	06-FEB-1979	500 METERS FROM SW CORNER			2	385.1	20.1
79330	13-JUL-1979	500 METERS FROM SW CORNER	557	8	1	234.3	27.2
79330	13-JUL-1979	500 METERS FROM SW CORNER			2	184.9	21.6
79330	13-JUL-1979	500 METERS FROM SW CORNER			3	108.2	10.3
79330	13-JUL-1979	500 METERS FROM SW CORNER			4	187.5	18.7
79330	13-JUL-1979	500 METERS FROM SW CORNER			5	50.9	5.3
79337	07-AUG-1979	500 METERS FROM SW CORNER	1682	46	1	238.9	30.1
79337	07-AUG-1979	500 METERS FROM SW CORNER			2	110.9	14.3
79337	10-AUG-1979	500 METERS FROM SW CORNER			3	150.4	15.0
79337	10-AUG-1979	500 METERS FROM SW CORNER			4	168.2	20.9
79337	10-AUG-1979	500 METERS FROM SW CORNER			5	162.7	18.3
79370	12-OCT-1979	500 METERS FROM SW CORNER	4	17	1	481.3	41.4
79370	12-OCT-1979	500 METERS FROM SW CORNER			2	260.5	18.0
79370	12-OCT-1979	500 METERS FROM SW CORNER			3	380.6	28.5
79370	12-OCT-1979	500 METERS FROM SW CORNER			4	228.3	20.6
79370	12-OCT-1979	500 METERS FROM SW CORNER			5	407.9	34.7
79383	06-NOV-1979	500 METERS FROM SW CORNER	15	18	1	214.9	18.4
79383	06-NOV-1979	500 METERS FROM SW CORNER			2	253.0	17.8
79383	06-NOV-1979	500 METERS FROM SW CORNER			3	238.9	17.1
79383	06-NOV-1979	500 METERS FROM SW CORNER			4	196.6	14.2
79383	06-NOV-1979	500 METERS FROM SW CORNER			5	412.1	31.2
79399	11-DEC-1979	500 METERS FROM SW CORNER	186	33	1	319.3	27.3
79399	11-DEC-1979	500 METERS FROM SW CORNER			2	310.7	27.5
79399	11-DEC-1979	500 METERS FROM SW CORNER			3	416.5	31.9
79399	11-DEC-1979	500 METERS FROM SW CORNER			4	257.9	27.8
79399	11-DEC-1979	500 METERS FROM SW CORNER			5	341.4	26.7
80201	07-JAN-1980	500 METERS FROM SW CORNER	159	47	1	343.7	27.7
80201	07-JAN-1980	500 METERS FROM SW CORNER			2	261.1	21.6
80201	07-JAN-1980	500 METERS FROM SW CORNER			3	263.8	20.8
80201	07-JAN-1980	500 METERS FROM SW CORNER			4	317.2	28.1
80201	07-JAN-1980	500 METERS FROM SW CORNER			5	347.2	31.6
80217	11-FEB-1980	500 METERS FROM SW CORNER	438	70	1	311.8	23.4
80217	11-FEB-1980	500 METERS FROM SW CORNER			2	307.5	23.0
80217	11-FEB-1980	500 METERS FROM SW CORNER			3	243.2	19.9
80217	11-FEB-1980	500 METERS FROM SW CORNER			4	282.5	21.6
80217	11-FEB-1980	500 METERS FROM SW CORNER			5	234.6	17.9
80227	11-MAR-1980	500 METERS FROM SW CORNER	45	33	1	46.6	3.3
80227	11-MAR-1980	500 METERS FROM SW CORNER			2	117.6	9.3
80227	11-MAR-1980	500 METERS FROM SW CORNER			3	176.5	13.0
80227	11-MAR-1980	500 METERS FROM SW CORNER			4	113.8	8.6
80227	11-MAR-1980	500 METERS FROM SW CORNER			5	15.1	1.2
80241	07-APR-1980	500 METERS FROM SW CORNER	210	20	1	45.8	3.2
80241	07-APR-1980	500 METERS FROM SW CORNER			2	110.0	[illegible]
80241	07-APR-1980	500 METERS FROM SW CORNER			3	74.4	[illegible]
80241	07-APR-1980	500 METERS FROM SW CORNER			4	191.1	14.3
80241	07-APR-1980	500 METERS FROM SW CORNER			5	81.6	6.0

COLL NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
80252	06-MAY-1980	500 METERS FROM SW CORNER	188	30	1	410.4	26.0
80252	06-MAY-1980	500 METERS FROM SW CORNER			2	224.7	14.1
80252	06-MAY-1980	500 METERS FROM SW CORNER			3	148.7	10.0
80252	06-MAY-1980	500 METERS FROM SW CORNER			4	163.1	14.2
80252	06-MAY-1980	500 METERS FROM SW CORNER			5	137.2	12.5
80259	09-JUN-1980	500 METERS FROM SW CORNER	671	104	1	453.6	34.7
80259	09-JUN-1980	500 METERS FROM SW CORNER			2	233.6	24.0
80259	09-JUN-1980	500 METERS FROM SW CORNER			3	411.8	35.9
80259	09-JUN-1980	500 METERS FROM SW CORNER			4	213.2	20.6
80259	09-JUN-1980	500 METERS FROM SW CORNER			5	327.2	24.8
80264	08-JUL-1980	500 METERS FROM SW CORNER	53	56	1	133.9	14.6
80264	08-JUL-1980	500 METERS FROM SW CORNER			2	181.9	20.7
80264	08-JUL-1980	500 METERS FROM SW CORNER			3	334.6	34.2
80264	08-JUL-1980	500 METERS FROM SW CORNER			4	308.6	37.7
80264	08-JUL-1980	500 METERS FROM SW CORNER			5	308.2	33.8
80268	17-OCT-1980	500 METERS FROM SW CORNER	69	136	1	284.3	23.0
80268	17-OCT-1980	500 METERS FROM SW CORNER			2	208.0	15.2
80268	17-OCT-1980	500 METERS FROM SW CORNER			3	205.0	16.2
80268	17-OCT-1980	500 METERS FROM SW CORNER			4	322.9	27.2
80268	17-OCT-1980	500 METERS FROM SW CORNER			5	322.6	27.7
80275	19-AUG-1980	500 METERS FROM SW CORNER	486	16	1	.	.
80275	19-AUG-1980	500 METERS FROM SW CORNER			2	.	.
80275	19-AUG-1980	500 METERS FROM SW CORNER			3	.	.
80275	19-AUG-1980	500 METERS FROM SW CORNER			4	.	.
80275	19-AUG-1980	500 METERS FROM SW CORNER			5	.	.

APPENDIX I: QUANTITATIVE HYDRILLA RESULTS FOR RODMAN RESERVOIR, PUTNAM COUNTY, FLORIDA

COLL NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL	135	0	1	520.4	31.7
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL			2	[illegible]	[illegible]
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL			3	413.0	21.4
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL			4	406.0	20.6
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL			5	496.4	[illegible]
78250	08-DEC-1978	END OF RODMAN BOAT TRAIL			6	488.1	24.8
79265	11-JAN-1980	END OF RODMAN BOAT TRAIL	48	28	1	[illegible]	18.2
79265	11-JAN-1980	END OF RODMAN BOAT TRAIL			2	189.8	12.5
79265	11-JAN-1980	END OF RODMAN BOAT TRAIL			3	326.5	22.8
79265	11-JAN-1980	END OF RODMAN BOAT TRAIL			4	234.6	15.2
79265	11-JAN-1980	END OF RODMAN BOAT TRAIL			5	341.8	21.8
79276	08-FEB-1979	END OF RODMAN BOAT TRAIL	136	19	1	84.2	[illegible]
79276	08-FEB-1979	END OF RODMAN BOAT TRAIL			2	126.7	7.5
79276	08-FEB-1979	END OF RODMAN BOAT TRAIL			3	45.5	2.6
79276	08-FEB-1979	END OF RODMAN BOAT TRAIL			4	130.4	7.7
79276	08-FEB-1979	END OF RODMAN BOAT TRAIL			5	132.3	7.5
79295	11-APR-1979	START OF RODMAN BOAT TRAIL	536	24	1	224.1	14.3
79295	11-APR-1979	START OF RODMAN BOAT TRAIL			2	231.3	14.0
79295	11-APR-1979	START OF RODMAN BOAT TRAIL			3	317.9	21.7
79295	11-APR-1979	START OF RODMAN BOAT TRAIL			4	268.4	20.4
79295	11-APR-1979	START OF RODMAN BOAT TRAIL			5	258.3	16.2
79308	10-MAY-1979	START OF RODMAN BOAT TRAIL	12	57	1	367.1	31.3
79308	10-MAY-1979	START OF RODMAN BOAT TRAIL			2	409.7	32.5
79308	10-MAY-1979	START OF RODMAN BOAT TRAIL			3	361.3	31.2
79308	10-MAY-1979	START OF RODMAN BOAT TRAIL			4	301.4	25.3
79308	10-MAY-1979	START OF RODMAN BOAT TRAIL			5	400.0	28.5
79315	05-JUN-1979	START OF RODMAN BOAT TRAIL	152	39	1	158.4	12.2
79315	05-JUN-1979	START OF RODMAN BOAT TRAIL			2	328.5	26.1
79315	05-JUN-1979	START OF RODMAN BOAT TRAIL			3	376.5	31.8
79315	05-JUN-1979	START OF RODMAN BOAT TRAIL			4	284.5	24.7
79315	05-JUN-1979	START OF RODMAN BOAT TRAIL			5	292.6	27.4
79327	11-JUL-1979	START OF RODMAN BOAT TRAIL	17	18	1	236.3	20.1
79327	11-JUL-1979	START OF RODMAN BOAT TRAIL			2	369.3	29.2
79327	11-JUL-1979	START OF RODMAN BOAT TRAIL			3	368.2	28.5
79327	11-JUL-1979	START OF RODMAN BOAT TRAIL			4	287.5	[illegible]
79327	11-JUL-1979	START OF RODMAN BOAT TRAIL			5	287.9	23.8
79336	07-AUG-1979	START OF RODMAN BOAT TRAIL	19	56	1	397.3	36.3
79336	07-AUG-1979	START OF RODMAN BOAT TRAIL			2	348.5	32.6
79336	07-AUG-1979	START OF RODMAN BOAT TRAIL			3	366.2	34.6
79336	07-AUG-1979	START OF RODMAN BOAT TRAIL			4	272.3	29.1
79336	07-AUG-1979	START OF RODMAN BOAT TRAIL			5	261.0	26.5
79367	10-OCT-1979	START OF RODMAN BOAT TRAIL	28	20	1	143.0	14.4
79367	10-OCT-1979	START OF RODMAN BOAT TRAIL			2	292.2	17.3
79367	10-OCT-1979	START OF RODMAN BOAT TRAIL			3	204.5	16.3
79367	10-OCT-1979	START OF RODMAN BOAT TRAIL			4	209.3	17.9
79367	10-OCT-1979	START OF RODMAN BOAT TRAIL			5	293.2	22.9

COLL.NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79394	12-NOV-1979	END OF RODMAN BOAT TRAIL	42	134	1	71.9	6.1
79394	12-NOV-1979	END OF RODMAN BOAT TRAIL			2	75.8	6.3
79394	12-NOV-1979	END OF RODMAN BOAT TRAIL			3	56.3	4.7
79394	12-NOV-1979	END OF RODMAN BOAT TRAIL			4	58.6	4.9
79394	12-NOV-1979	END OF RODMAN BOAT TRAIL			5	103.8	8.8
79401	11-DEC-1979	END OF RODMAN BOAT TRAIL	128	128	1	126.5	11.2
79401	11-DEC-1979	END OF RODMAN BOAT TRAIL			2	190.0	14.9
79401	11-DEC-1979	END OF RODMAN BOAT TRAIL			3	141.2	11.5
79401	11-DEC-1979	END OF RODMAN BOAT TRAIL			4	131.0	10.4
79401	11-DEC-1979	END OF RODMAN BOAT TRAIL			5	217.8	18.4
80203	08-JAN-1980	END OF RODMAN BOAT TRAIL	285	214	1	202.7	8.9
80203	08-JAN-1980	END OF RODMAN BOAT TRAIL			2	270.1	13.0
80203	08-JAN-1980	END OF RODMAN BOAT TRAIL			3	199.1	10.4
80203	08-JAN-1980	END OF RODMAN BOAT TRAIL			4	276.9	12.6
80203	08-JAN-1980	END OF RODMAN BOAT TRAIL			5	242.2	11.8
80214	08-FEB-1980	END OF RODMAN BOAT TRAIL	172	296	1	127.3	10.1
80214	08-FEB-1980	END OF RODMAN BOAT TRAIL			2	166.7	12.3
80214	08-FEB-1980	END OF RODMAN BOAT TRAIL			3	156.5	12.4
80214	08-FEB-1980	END OF RODMAN BOAT TRAIL			4	189.8	14.6
80214	08-FEB-1980	END OF RODMAN BOAT TRAIL			5	135.1	10.2
80229	11-MAR-1980	END OF RODMAN BOAT TRAIL	68	49	1	6.2	0.4
80229	11-MAR-1980	END OF RODMAN BOAT TRAIL			2	13.6	0.7
80229	11-MAR-1980	END OF RODMAN BOAT TRAIL			3	33.9	2.1
80229	11-MAR-1980	END OF RODMAN BOAT TRAIL			4	11.8	0.7
80229	11-MAR-1980	END OF RODMAN BOAT TRAIL			5	34.0	2.1
80240	06-APR-1980	END OF RODMAN BOAT TRAIL	724	151	1	114.8	7.5
80240	06-APR-1980	END OF RODMAN BOAT TRAIL			2	29.0	2.0
80240	06-APR-1980	END OF RODMAN BOAT TRAIL			3	2.9	0.1
80240	06-APR-1980	END OF RODMAN BOAT TRAIL			4	12.2	1.2
80240	06-APR-1980	END OF RODMAN BOAT TRAIL			5	4.8	0.2
80258	09-JUN-1980	END OF RODMAN BOAT TRAIL	481	9	1	111.3	14.3
80258	09-JUN-1980	END OF RODMAN BOAT TRAIL			2	119.1	13.7
80258	09-JUN-1980	END OF RODMAN BOAT TRAIL			3	75.2	9.2
80258	09-JUN-1980	END OF RODMAN BOAT TRAIL			4	58.3	6.6
80258	09-JUN-1980	END OF RODMAN BOAT TRAIL			5	109.1	13.3
80263	07-JUL-1980	END OF RODMAN BOAT TRAIL	124	20	1	114.2	106.5
80263	07-JUL-1980	END OF RODMAN BOAT TRAIL			2	161.0	111.8
80263	07-JUL-1980	END OF RODMAN BOAT TRAIL			3	.	119.2
80263	07-JUL-1980	END OF RODMAN BOAT TRAIL			4	153.6	11.8
80263	07-JUL-1980	END OF RODMAN BOAT TRAIL			5	.	10.3
80274	19-AUG-1980	END OF RODMAN BOAT TRAIL	14	0	1	.	.
80274	19-AUG-1980	END OF RODMAN BOAT TRAIL			2	.	.
80274	19-AUG-1980	END OF RODMAN BOAT TRAIL			3	.	.
80274	19-AUG-1980	END OF RODMAN BOAT TRAIL			4	.	.
80274	19-AUG-1980	END OF RODMAN BOAT TRAIL			5	87.9	8.3

APPENDIX J: QUANTITATIVE HYDRILLA RESULTS FOR THE CRYSTAL RIVER, CITRUS COUNTY, FLORIDA

COLL.NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
78246	08-DEC-1978	MOUTH OF MILLER'S CREEK	0	0	1	29.5	2.2
78246	08-DEC-1978	MOUTH OF MILLER'S CREEK			2	51.9	2.7
78246	08-DEC-1978	MOUTH OF MILLER'S CREEK			3	48.3	2.3
78246	08-DEC-1978	MOUTH OF MILLER'S CREEK			4	152.4	7.7
78246	08-DEC-1978	MOUTH OF MILLER'S CREEK			5	.	.
78247	08-DEC-1978	NORTH END OF KING'S BAY	24	0	1	191.0	9.3
78247	08-DEC-1978	NORTH END OF KING'S BAY			2	143.3	6.2
78247	08-DEC-1978	NORTH END OF KING'S BAY			3	155.8	7.5
78247	08-DEC-1978	NORTH END OF KING'S BAY			4	163.9	7.4
79262	11-JAN-1979	MOUTH OF MILLER'S CREEK	0	7	1	18.4	1.6
79262	11-JAN-1979	MOUTH OF MILLER'S CREEK			2	17.8	1.1
79262	11-JAN-1979	MOUTH OF MILLER'S CREEK			3	21.9	1.3
79262	11-JAN-1979	MOUTH OF MILLER'S CREEK			4	68.5	6.1
79262	11-JAN-1979	MOUTH OF MILLER'S CREEK			5	33.8	3.2
79263	11-JAN-1979	NORTH END OF KING'S BAY	2	53	1	39.9	2.2
79263	11-JAN-1979	NORTH END OF KING'S BAY			2	73.2	3.8
79263	11-JAN-1979	NORTH END OF KING'S BAY			3	55.0	2.8
79263	11-JAN-1979	NORTH END OF KING'S BAY			4	28.4	1.5
79263	11-JAN-1979	NORTH END OF KING'S BAY			5	37.1	2.2
79274	08-FEB-1979	MOUTH OF MILLER'S CREEK	30	6	1	169.2	12.8
79274	08-FEB-1979	MOUTH OF MILLER'S CREEK			2	169.0	15.0
79274	08-FEB-1979	MOUTH OF MILLER'S CREEK			3	308.0	39.9
79274	08-FEB-1979	MOUTH OF MILLER'S CREEK			4	163.2	17.2
79274	08-FEB-1979	MOUTH OF MILLER'S CREEK			5	200.1	20.4
79319	07-JUN-1979	MOUTH OF MILLER'S CREEK	8	56	1	255.1	25.6
79319	07-JUN-1979	MOUTH OF MILLER'S CREEK			2	226.9	25.0
79319	07-JUN-1979	MOUTH OF MILLER'S CREEK			3	237.0	26.6
79319	07-JUN-1979	MOUTH OF MILLER'S CREEK			4	219.8	24.6
79319	07-JUN-1979	MOUTH OF MILLER'S CREEK			5	228.1	23.0
79329	12-JUL-1979	MOUTH OF MILLER'S CREEK	19	63	1	437.5	55.1
79329	12-JUL-1979	MOUTH OF MILLER'S CREEK			2	412.4	45.2
79329	12-JUL-1979	MOUTH OF MILLER'S CREEK			3	351.5	46.6
79329	12-JUL-1979	MOUTH OF MILLER'S CREEK			4	262.4	29.7
79329	12-JUL-1979	MOUTH OF MILLER'S CREEK			5	285.7	30.4
79341	09-AUG-1979	MOUTH OF MILLER'S CREEK	52	123	1	74.5	12.3
79341	09-AUG-1979	MOUTH OF MILLER'S CREEK			2	98.9	12.1
79341	09-AUG-1979	MOUTH OF MILLER'S CREEK			3	86.2	12.3
79341	09-AUG-1979	MOUTH OF MILLER'S CREEK			4	74.0	10.3
79341	09-AUG-1979	MOUTH OF MILLER'S CREEK			5	92.5	13.0
79369	11-OCT-1979	MOUTH OF MILLER'S CREEK	35	72	1	119.8	15.4
79369	11-OCT-1979	MOUTH OF MILLER'S CREEK			2	156.0	17.4
79369	11-OCT-1979	MOUTH OF MILLER'S CREEK			3	75.7	12.4
79369	11-OCT-1979	MOUTH OF MILLER'S CREEK			4	92.6	19.5
79369	11-OCT-1979	MOUTH OF MILLER'S CREEK			5	346.4	40.2

COLL NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79406	14-DEC-1979	MOUTH OF MILLER'S CREEK	75	149	1	180.9	13.7
79406	14-DEC-1979	MOUTH OF MILLER'S CREEK			2	167.7	12.2
79406	14-DEC-1979	MOUTH OF MILLER'S CREEK			3	76.9	5.6
79406	14-DEC-1979	MOUTH OF MILLER'S CREEK			4	136.3	9.3
79406	14-DEC-1979	MOUTH OF MILLER'S CREEK			5	118.9	9.9
79413	09-NOV-1979	MOUTH OF MILLER'S CREEK	7	72	1	139.6	12.1
79413	09-NOV-1979	MOUTH OF MILLER'S CREEK			2	173.7	15.1
79413	09-NOV-1979	MOUTH OF MILLER'S CREEK			3	211.7	19.0
79413	09-NOV-1979	MOUTH OF MILLER'S CREEK			4	198.7	16.6
79413	09-NOV-1979	MOUTH OF MILLER'S CREEK			5	193.5	14.1
80207	10-JAN-1980	MOUTH OF MILLER'S CREEK	82	84	1	30.3	2.2
80207	10-JAN-1980	MOUTH OF MILLER'S CREEK			2	106.8	10.3
80207	10-JAN-1980	MOUTH OF MILLER'S CREEK			3	53.6	5.0
80207	10-JAN-1980	MOUTH OF MILLER'S CREEK			4	71.3	6.4
80207	10-JAN-1980	MOUTH OF MILLER'S CREEK			5	27.0	2.0
80215	11-FEB-1980	MOUTH OF MILLER'S CREEK	21	32	1	17.7	1.7
80215	11-FEB-1980	MOUTH OF MILLER'S CREEK			2	3.1	0.4
80215	11-FEB-1980	MOUTH OF MILLER'S CREEK			3	12.1	1.5
80215	11-FEB-1980	MOUTH OF MILLER'S CREEK			4	8.3	0.9
80215	11-FEB-1980	MOUTH OF MILLER'S CREEK			5	36.7	4.2

APPENDIX K: QUANTITATIVE HYDRILLA RESULTS FOR THE SR 841 CANAL, COLLIER COUNTY, FLORIDA

COLL NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79255	05-JAN-1979	NORTH OF SR 837 JUNCTION	9	0	1	749.6	47.9
79255	05-JAN-1979	NORTH OF SR 837 JUNCTION			2	869.8	63.5
79255	05-JAN-1979	NORTH OF SR 837 JUNCTION			3	248.7	15.7
79255	05-JAN-1979	NORTH OF SR 837 JUNCTION			4	494.5	25.7
79255	05-JAN-1979	NORTH OF SR 837 JUNCTION			5	522.4	37.2
79268	01-FEB-1979	FOOTBRIDGE,2.8 MI N OF US 41	355	201	1	608.5	55.4
79268	01-FEB-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	561.6	49.5
79268	01-FEB-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	572.8	47.8
79268	01-FEB-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	636.9	56.0
79268	01-FEB-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	611.5	63.6
79287	20-MAR-1979	FOOTBRIDGE,2.8 MI N OF US 41	29	136	1	508.2	48.9
79287	20-MAR-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	456.8	46.4
79287	20-MAR-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	531.8	51.3
79287	20-MAR-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	434.7	42.9
79287	20-MAR-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	437.5	40.0
79300	19-APR-1979	FOOTBRIDGE,2.8 MI N OF US 41	21	56	1	543.6	51.2
79300	19-APR-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	585.8	63.0
79300	19-APR-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	806.8	83.4
79300	19-APR-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	588.6	56.3
79300	19-APR-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	444.7	43.6
79311	17-MAY-1979	FOOTBRIDGE,2.8 MI N OF US 41	13	61	1	331.4	39.0
79311	17-MAY-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	405.9	45.1
79311	17-MAY-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	324.6	36.0
79311	17-MAY-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	369.0	42.6
79311	17-MAY-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	430.3	46.2
79322	14-JUN-1979	FOOTBRIDGE,2.8 MI N OF US 41	65	240	1	450.1	42.1
79322	14-JUN-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	483.7	44.2
79322	14-JUN-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	492.0	43.3
79322	14-JUN-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	515.3	76.5
79322	14-JUN-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	520.0	42.2
79334	18-JUL-1979	FOOTBRIDGE,2.8 MI N OF US 41	69	145	1	234.5	22.9
79334	18-JUL-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	403.5	42.0
79334	18-JUL-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	477.0	48.1
79334	18-JUL-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	571.0	46.5
79334	18-JUL-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	694.9	71.0
79361	13-SEP-1979	FOOTBRIDGE,2.8 MI N OF US 41	9	75	1	713.3	78.1
79361	13-SEP-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	670.2	76.3
79361	13-SEP-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	644.7	86.2
79361	13-SEP-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	568.3	68.2
79361	13-SEP-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	357.9	40.6
79375	19-OCT-1979	FOOTBRIDGE,2.8 MI N OF US 41	68	172	1	268.6	33.6
79375	19-OCT-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	253.4	28.8
79375	19-OCT-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	260.1	30.9
79375	19-OCT-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	281.8	32.0
79375	19-OCT-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	212.8	23.4
79398	20-NOV-1979	FOOTBRIDGE,2.8 MI N OF US 41	28	41	1	972.5	73.8
79398	20-NOV-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	1126.1	84.6
79398	20-NOV-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	1113.6	98.1
79398	20-NOV-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	1141.8	98.2
79398	20-NOV-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	1245.1	89.0

COLL.NO	DATE	LOCATION	TOTAL INSECTS	TOTAL SNAILS	SAMPLE NUMBER	WET WEIGHT	DRY WEIGHT
79410	20-DEC-1979	FOOTBRIDGE,2.8 MI N OF US 41	25	16	1	240.9	21.7
79410	20-DEC-1979	FOOTBRIDGE,2.8 MI N OF US 41			2	199.0	19.5
79410	20-DEC-1979	FOOTBRIDGE,2.8 MI N OF US 41			3	122.3	10.5
79410	20-DEC-1979	FOOTBRIDGE,2.8 MI N OF US 41			4	228.9	17.7
79410	20-DEC-1979	FOOTBRIDGE,2.8 MI N OF US 41			5	208.7	18.6
80212	17-JAN-1980	FOOTBRIDGE,2.8 MI N OF US 41	23	33	1	165.4	15.0
80212	17-JAN-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	226.6	20.0
80212	17-JAN-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	278.4	23.1
80212	17-JAN-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	174.0	18.6
80212	17-JAN-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	150.8	14.1
80225	21-FEB-1980	FOOTBRIDGE,2.8 MI N OF US 41	22	12	1	66.7	6.4
80225	21-FEB-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	89.2	8.8
80225	21-FEB-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	41.7	3.6
80225	21-FEB-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	103.8	10.1
80225	21-FEB-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	85.1	7.4
80238	20-MAR-1980	FOOTBRIDGE,2.8 MI N OF US 41	2	11	1	31.5	1.9
80238	20-MAR-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	62.7	4.2
80238	20-MAR-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	17.2	1.0
80238	20-MAR-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	30.4	2.2
80238	20-MAR-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	28.8	1.8
80251	17-APR-1980	FOOTBRIDGE,2.8 MI N OF US 41	15	6	1	327.9	30.9
80251	17-APR-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	382.8	39.1
80251	17-APR-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	383.6	32.8
80251	17-APR-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	320.2	23.5
80251	17-APR-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	253.2	18.5
80257	15-MAY-1980	FOOTBRIDGE,2.8 MI N OF US 41	6	24	1	307.8	32.4
80257	15-MAY-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	301.9	34.0
80257	15-MAY-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	327.4	31.1
80257	15-MAY-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	332.1	28.1
80257	15-MAY-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	196.8	16.6
80262	16-JUN-1980	FOOTBRIDGE,2.8 MI N OF US 41	162	55	1	440.3	41.3
80262	16-JUN-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	494.1	49.6
80262	16-JUN-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	297.3	33.7
80262	16-JUN-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	291.0	35.6
80262	16-JUN-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	308.9	33.5
80267	18-JUL-1980	FOOTBRIDGE,2.8 MI N OF US 41	60	32	1	218.3	33.2
80267	18-JUL-1980	FOOTBRIDGE,2.8 MI N OF US 41			2	272.4	41.5
80267	18-JUL-1980	FOOTBRIDGE,2.8 MI N OF US 41			3	260.3	48.1
80267	18-JUL-1980	FOOTBRIDGE,2.8 MI N OF US 41			4	337.7	77.2
80267	18-JUL-1980	FOOTBRIDGE,2.8 MI N OF US 41			5	271.9	68.9

APPENDIX L: SUMMARY OF INSECT TAXA COLLECTED ON *HYDRILLA VERTICILLATA*

ORDER	SPECIMENS COLLECTED	% OF TOTAL SPECIMENS (N=17,398)	NUMBER OF COLLECTIONS	% OF TOTAL COLLECTIONS (N=289)	NUMBER OF SITES	% OF TOTAL SITES (N=75)
DIPTERA	9919	57	187	65	37	49
TRICHOPTERA	4265	24	159	55	26	35
ODONATA	1178	07	185	64	41	55
COLEOPTERA	663	04	71	25	22	29
HEMIPTERA	573	03	94	33	29	39
EPHEMEROPTERA	432	02	98	34	27	36
LEPIDOPTERA	360	02	38	13	19	25
HOMOPTERA	4	< 01	2	< 01	2	03
HYMENOPTERA	2	< 01	2	< 01	2	03
NEUROPTERA	2	< 01	2	< 01	2	03

APPENDIX M: SNAILS ASSOCIATED WITH *HYDRILLA VERTICILLATA*

NAME	STATE	SPECIMENS	COLLECTIONS
Class Mollusca			
Order Gastropoda			
Family AMPULLARIDAE			
Marisa cornuarietis	Florida	11	79277
Pomacea paludosa	Florida	27	78211,78248,79261,79277, 79295,79320,79324,79333, 79358,79360,79398,80209, 80255,80256,80262
	Georgia	2	78202
Family ANCYLIDAE			
Gundlachia species	Florida	1	79290
Hebetancylus excentricus	Florida	103	79256,79286,79288,79290, 79294,79299,79310,79342, 79348,79356,79358,79368, 79374,80214,80229,80240
Laevapex species	Florida	99	79284,79286,79288,79290, 79299,79315,79332,79353, 79363,79371,79386,79387, 79396,79400,79403,79409, 80203,80204,80228,80240, 80250,80254,80255,80257, 80260
	Louisiana	1	79371
Family HYDROBIIDAE			
Amnicola dalli	Florida	1513	78205,78207,78208,79273, 79282,79306,79318,79326, 79327,79340,79353,79366, 79367,79369,79385,79402, 79403,80203,80206,80214, 80219,80221,80231,80233, 80234,80240,80243,80247, 80255,80263
	Louisiana	163	78242,79381
Amnicola spp.	Panama	16	80273
	Texas	5	80272
Aphaostracon pachynotus	Florida	472	78211,79309,79320,79332, 79346,79358,79372,79373, 79395,79407,79408,80209, 80210,80236,80248,80249, 80256,80261,80266

NAME	STATE	SPECIMENS	COLLECTIONS
Hydrobia species	Florida	8	79262,80249
Littoridinops monroensis	Florida	379	78205,78207,78211,78225, 79253,79262,79263,79298, 79307,79319,79329,79341, 79345,79350,79358,79369, 79372,79395,79406,79407, 79413,80207,80209,80215, 80230,80248,80260
Littoridinops species	Texas	2	79377
Notosillia wetherbyi	Florida	17	78211,79316,79366,80253
Pyrgophorus platyrachis	Florida	16	78205,79320
Pyrgophorus species	Texas	19	80270
Family LYMNAEIDAE			
Lymnaea species	Florida	3	80250
Family NERITIDAE			
Neritina species	Florida	1312	78204,79273,79274,79282, 79293,79306,79318,79319, 79326,79340,79341,79353, 79355,79366,79369,79385, 79402,80206,80215,80221, 80234,80247
Family PHYSIDAE			
Physa spp.	Florida	3763	78206,78207,78208,78209, 78211,78212,78235,79253, 79263,79264,79265,79266, 79267,79268,79269,79270, 79272,79273,79274,79275, 79277,79282,79283,79284, 79285,79286,79287,79288, 79289,79293,79294,79295, 79296,79297,79298,79299, 79300,79301,79302,79303, 79305,79306,79307,79308, 79309,79311,79313,79317, 79318,79319,79320,79322, 79323,79324,79325,79326, 79327,79328,79329,79330, 79331,79332,79334,79336, 79337,79338,79339,79340, 79341,79342,79343,79345, 79347,79349,79351,79352, 79353,79355,79356,79358,

NAME	STATE	SPECIMENS	COLLECTIONS
Physa spp. (continued)			79359,79361,79362,79363, 79364,79365,79366,79368, 79369,79370,79371,79372, 79373,79375,79383,79385, 79386,79388,79393,79394, 79395,79396,79398,79400, 79401,79402,79403,79404, 79405,79406,79407,79408, 79410,79411,79412,79413, 80201,80202,80203,80204, 80205,80206,80207,80208, 80210,80212,80214,80215, 80216,80217,80218,80219, 80220,80221,80223,80225, 80227,80228,80229,80231, 80232,80233,80234,80236, 80239,80240,80241,80242, 80243,80245,80246,80249, 80250,80252,80254,80255, 80256,80257,80259,80260, 80261,80262,80263,80264, 80265,80266,80267,80268, 80275
	Louisiana	20	79381
	Texas	220	79378,79380,80270,80272
	Georgia	105	79389,79390
	Panama	9	79312,80273
Family PLANORBIDAE			
Gyraulus spp.	Florida	4068	78206,78207,78208,78209, 78212,78224,79253,79262, 79263,79264,79265,79267, 79268,79269,79272,79273, 79275,79276,79278,79283, 79284,79287,79288,79289, 79290,79292,79293,79295, 79296,79297,79299,79301, 79302,79305,79306,79307, 79308,79310,79315,79317, 79318,79319,79320,79321, 79322,79323,79325,79326, 79327,79328,79329,79332, 79333,79334,79337,79338, 79340,79341,79342,79345, 79346,79348,79349,79351, 79353,79354,79356,79358, 79360,79362,79363,79366, 79367,79369,79370,79371, 79372,79374,79375,79388, 79393,79394,79395,79396, 79400,79401,79402,79403, 79404,79405,79406,79407, 79409,79410,79411,79412, 79413,80202,80203,80204,

NAME	STATE	SPECIMENS	COLLECTIONS
Gryaulus spp. (continued)			80205,80206,80207,80208, 80209,80212,80214,80215, 80216,80219,80221,80225, 80228,80229,80231,80232, 80236,80239,80240,80242, 80243,80245,80249,80251, 80252,80253,80256,80257, 80258,80259,80261,80262, 80263,80264,80266,80267, 80268,80275
	Georgia	68	79389,79390
	Louisiana	105	79381
	Panama	2	79312
	Texas	71	79379,79380,80272
Helisoma scalare	Florida	3428	78203,78206,78207,78208, 78211,78221,78222,78225, 78248,79261,79264,79265, 79266,79268,79269,79270, 79271,79274,79275,79276, 79278,79279,79282,79284, 79285,79286,79287,79288, 79289,79290,79295,79296, 79297,79298,79300,79301, 79302,79305,79308,79309, 79310,79311,79313,79315, 79316,79317,79318,79320, 79321,79322,79323,79324, 79325,79327,79328,79330, 79331,79332,79334,79335, 79336,79337,79339,79340, 79343,79344,79345,79347, 79348,79349,79350,79351, 79352,79353,79354,79355, 79356,79358,79360,79361, 79362,79363,79364,79366, 79367,79368,79370,79371, 79372,79373,79375,79383, 79387,79393,79395,79396, 79398,79399,79400,79401, 79402,79403,79407,79410, 79411,79412,80201,80202, 80203,80204,80206,80208, 80210,80211,80212,80213, 80214,80216,80217,80218, 80219,80220,80221,80223, 80225,80226,80227,80228, 80229,80231,80233,80236, 80238,80240,80241,80242, 80246,80249,80250,80251, 80252,80254,80255,80256, 80257,80258,80259,80260, 80261,80262,80264,80265, 80266,80267,80268,80275
	Georgia	49	79390,79391
	Louisiana	14	79381
	Panama	26	79312,80273,80277

NAME	STATE	SPECIMENS	COLLECTIONS
Helisoma duryi	Florida	130	79288,79299,79311,79324, 79331,79336,79339,79344, 79352,79364,79371,79387, 79409,80260,80264,80265
	Louisiana	17	78242,79381
	Panama	23	79312,80273
Family PLERUOCERIDAE			
Goniobasis floridense	Florida	11227	78212,79262,79271,79272, 79277,79280,79286,79291, 79293,79304,79305,79316, 79324,79339,79352,79364, 79370,79386,79387,79403, 80204,80220,80233,80246, 80254,80255,80260,80265
	Texas	894	79377,80269,80270,80271, 80272
Goniobasis vanhyninsi	Florida	69	79268,79277,79300,79309, 79311,79321,79322,79348, 79349,79397,79409,80211, 80250
	Texas	2	79377
Goniobasis species	Panama	2	79312
Family VIVIPARIDAE			
Viviparus georgianus	Florida	6	78211,78248
Viviparus species	Florida	3	78222

APPENDIX N: INVERTEBRATES OTHER THAN INSECTS AND SNAILS ASSOCIATED WITH *HYDRILLA VERTICILLATA*

NAME	STATE	SPECIMENS	COLLECTIONS
Class Hirudinea			
Order Rhynchobdellida			
Family GLOSSIPHONIIDAE			
Helobdella stagnalis	Florida	299	79259,79268,79270,79278, 79279,79284,79288,79289, 79290,79297,79301,79302, 79303,79313,79330,79331, 79332,79343,79356,79370, 79371,79399,80201,80203, 80207,80217,80218,80229, 80231,80232,80240,80241, 80249,80259
	Texas	1	79377
Helobdella species	Florida	71	78227,78238,78243,79257, 79268,79270,79274,79279, 79283,79284,79287,79288, 79289,79290,79294,79300, 79301,79302,79303,79307, 79310,79311,79319,79329, 79348,79349,79352,79361, 79366,79406,79410,79411, 80246
	Louisiana	1	79381
Placobdella species A	Florida	63	79256,79257,79270,79272, 79279,79284,79286,79288, 79289,79290,79292,79296, 79300,79302,79303,79310, 79313,79321,79328,80203, 80219,80223,80240,80241, 80250,80252,80259,80264
Placobdella species B	Florida	1	79321
Family PISCICOLIDAE			
Illinobdella moorei	Florida	3	79370,80241,80252
Myzobdella lugubris	Florida	1	79288
Class Crustaceae			
Order Amphipoda			
Family GAMMARIDAE			
Gammarus species A	Florida	1440	78217,78243,78247,78251, 78252,79256,79257,79258, 79260,79261,79262,79263, 79264,79268,79269,79270, 79271,79272,79273,79274, 79276,79278,79279,79281, 79282,79284,79285,79286, 79288,79289,79290,79291,

NAME	STATE	SPECIMENS	COLLECTIONS
<u>Gammarus</u> species A (continued)			79292,79293,79295,79296, 79298,79299,79301,79302, 79303,79304,79306,79307, 79313,79314,79316,79333, 79337,79338,79343,79345, 79348,79351,79353,79355, 79362,79363,79364,79366, 79367,79369,79370,79372, 79375,79383,79394,79397, 79398,79399,79400,79401, 79402,79404,79405,79406, 79407,79410,79411,79412, 79413,80201,80202,80203, 80205,80206,80207,80212, 80213,80214,80215,80216, 80217,80218,80219,80221, 80225,80226,80228,80229, 80231,80235,80236,80239, 80240,80241,80242,80243, 80249,80252,80254,80255, 80258,80259,80260,80262, 80263,80264,80265,80266, 80267,80275
	Louisiana	17	79381
<u>Gammarus</u> species B	Florida	70	79274,79406,80207,80215, 80262
Family TACITRIDAE			
<u>Hyallela azteca</u>	Florida	3522	78210,78214,78217,78221, 78243,78247,78251,78252, 79253,79256,79257,79258, 79259,79260,79262,79263, 79264,79265,79268,79269, 79270,79271,79272,79273, 79274,79275,79276,79278, 79279,79281,79282,79284, 79285,79286,79288,79289, 79290,79291,79292,79293, 79295,79296,79299,79301, 79302,79303,79306,79307, 79313,79314,79316,79328, 79332,79333,79335,79337, 79338,79341,79342,79343, 79345,79348,79349,79350, 79351,79353,79354,79355, 79356,79357,79362,79363, 79365,79366,79367,79369, 79370,79375,79383,79385, 79388,79394,79399,79400, 79401,79402,79404,79405, 79406,79410,79411,79412, 79413,80201,80202,80203, 80205,80206,80207,80208,

NAME	STATE	SPECIMENS	COLLECTIONS
Hyallela azteca (continued)			80209,80212,80213,80214,80215,80216,80217,80218,80219,80221,80223,80225,80226,80227,80228,80229,80230,80231,80232,80234,80236,80239,80240,80241,80242,80243,80245,80249,80252,80253,80254,80255,80258,80259,80260,80261,80262,80263,80264,80265,80266,80267,80268,80275
	Louisiana	23	79381
	Texas	6	79379,80269
Undetermined Amphipoda	Florida	78	78205,78243,79262,79263,79363,79368,79369,80216,80217,80242,80252,80255
	Louisiana	6	79381
Order Cladocera			
Family SIDIDAE			
Sida crystallina	Florida	15	80263
Order Decapoda			
Family ASTACIDAE			
Procambarus spp.	Florida	149	78205,78222,78249,78251,79253,79261,79262,79266,79268,79271,79274,79282,79288,79291,79300,79304,79308,79316,79321,79322,79324,79327,79334,79339,79349,79352,79361,79364,79366,79398,80233,80236,80254,80255,80260,80265
	Louisiana	5	79381
	Texas	1	80269
Family PALAEMONIDAE			
Palaemonetes spp.	Florida	5341	78205,78206,78213,78214,78217,78218,78221,78222,78224,78225,78226,78231,78233,78234,78235,78239,78240,78244,78246,78248,78249,78251,78252,78253,79254,79255,79259,79260,79261,79265,79266,79267,79268,79270,79271,79272,79274,79276,79280,79284,79285,79286,79287,79288,79291,79295,79298,79300,79301,79304,79305,79308,79309,79310,79311,79315,79316,79317,79319,79320,

NAME	STATE	SPECIMENS	COLLECTIONS
Palaemonetes spp. (continued)			79321,79322,79324,79325, 79326,79327,79329,79330, 79332,79333,79334,79336, 79337,79338,79339,79345, 79348,79349,79352,79354, 79355,79356,79361,79362, 79363,79364,79365,79366, 79367,79369,79370,79375, 79383,79385,79388,79394, 79397,79398,79399,79400, 79401,79403,79404,79406, 79408,79409,79410,79411, 79412,80201,80202,80203, 80204,80205,80207,80210, 80211,80212,80213,80214, 80217,80218,80219,80220, 80225,80227,80228,80229, 80232,80233,80237,80238, 80239,80240,80241,80243, 80244,80245,80246,80249, 80250,80251,80252,80254, 80255,80257,80258,80259, 80260,80262,80263,80264, 80265,80267,80275
	Louisiana	1	78242
Family PORTUNIDAE			
Callinectes sapidus	Florida	2	79246,79275
Family XANTHIDAE			
Rhithropanopeus harrisii	Florida	15	79274,79319,79329,79406
Order Isopoda			
Family SPHAEROMIDAE			
Sphaeroma terebrans	Florida	78	79262,79263,79274,79319, 79329,79341,79369,79406, 80207
Order Mysidacea			
Family MYSIDAE			
Taphromysis louisianae	Florida	23	79305,79385,79406,80207, 80215,80246
Order Ostracoda			
Undetermined species	Florida	75	79362,79363,80259,80263, 80266,80274,80275
Order Tanaidacea			
Family PARATANAIDAE			
Leptochelia savignyi	Florida	25	79262,79263,79274

NAME	STATE	SPECIMENS	COLLECTIONS
Class Arachnida Order Acari Family ARRENURIDAE			
Arrenurus spp.	Florida	32	78221,78245,79264,79311, 79338,79367,79371,79375, 79394,79396,79397,79404, 79409,80203,80204,80226, 80239,80267
Family HYDRACHNIDAE			
Hydrachna species	Florida	1	80256
Family HYDRODROMIDAE			
Hydrodroma despiciens	Florida	110	78247,79262,79263,79264, 79265,79275,79283,79311, 79319,79329,79367,79369, 79370,79394,79406,79410, 79412,79413,80203,80207, 80212,80215,80229,80238, 80240,80257,80258,80262, 80263,80267
Family KRENDOWSKIJIDAE			
Geayia species	Florida	4	79375,80256,80262
Family LEBERTIIDAE			
Lebertia spp.	Florida	13	78207,79264,79273,79280, 79326,79364,79387,80207, 80220,80255,80265
Family LIMNESIIDAE			
Limnesia spp.	Florida	7	78216,79317,79318,79375, 80226,80249
Family ORIBATIDAE			
Hydrozetes species	Florida	94	78216,79263,79268,79281, 79293,79311,79318,79338, 79345,79362,79363,79371, 79375,79388,79389,79394, 79402,79406,80207,80216, 80239,80242,80257
	Texas	5	79378
Family SPERCHONIDAE			
Sperchon species	Texas	2	79377,80272
Family TEUTONIIDAE			
Teutonia species	Florida	1	79319

NAME	STATE	SPECIMENS	COLLECTIONS
Family UNIONICOLIDAE Koenikea species	Florida	18	79347,79371,79368,79381, 80213,80236
Unionicola species	Florida	8	79264,79304,79307,80239
Undetermined Mites	Florida	9	79329,79375,80207,80260, 80275
Class Mollusca Order Pelecypoda Family CORBICULIDAE Corbicula manilensis	Florida	3	78248
Family MYTILIDAE Brachidontes species	Florida	7	79319,79329,79369,79406, 79413
Family SPHAERIIDAE Eupera cubensis	Florida	65	79307,79328,79393,79405, 80208,80214,80216,80231, 80243
	Louisiana	30	79381
Eupera species	Panama	2	80273
Sphaerium spp.	Florida	46	79253,79260,79287,79290, 79305,79325,79326,79353, 79366,79385,79409,80205, 80219,80228,80232,80242
	California	2	78236
Family UNIONIDAE Undetermined spp.	Florida	3	78248

APPENDIX O: AMPHIBIANS AND FISH ASSOCIATED WITH *HYDRILLA VERTICILLATA* IN FLORIDA

NAME	SPECIMENS	COLLECTIONS
Amphibians		
Order Caudata		
Family SALAMANDRIDAE		
Notophthalmus viridescens	1	80255
Order Salientia		
Family HYLIDAE		
Hyla species	10	80260,80265
Fish		
Order Atheriniformes		
Family CYPRINODONTIDAE		
Fundulus species A	3	79398
Fundulus species B	4	79334,80212
Fundulus species C	16	79255,79288,79300,79301, 79315,79319,79336,79369, 79398,80212,80238
Fundulus species D	1	79329
Jordanella floridae	53	79285,79286,79287,79288, 79322,79334,79336,79360, 79361,79375,79398,80212, 80238,80257,80262
Lucania goodei	346	78205,78251,78252,79253, 79261,79268,79271,79275, 79280,79283,79285,79287, 79288,79291,79295,79300, 79301,79304,79308,79311, 79315,79316,79319,79322, 79324,79327,79329,79334, 79336,79338,79339,79345, 79349,79352,79353,79355, 79361,79362,79364,79366, 79367,79369,79370,79375, 79383,79387,79398,79399, 79403,79406,79410,79411, 79413,80203,80204,80207, 80212,80213,80214,80215, 80220,80225,80233,80238, 80246,80251,80254,80255, 80257,80262,80265,80267, 80274

NAME	SPECIMENS	COLLECTIONS
Family POECILIIDAE		
<u>Gambusia</u> <u>affinis</u>	288	78251,79253,79265,79268, 79277,79280,79286,79287, 79288,79295,79300,79301, 79308,79311,79315,79316, 79327,79334,79336,79337, 79338,79349,79355,79362, 79364,79367,79375,79383, 79398,79411,80202,80203, 80214,80225,80237,80238, 80244,80257,80255,80257, 80260,80262,80265,80267, 80275
<u>Heterandria</u> <u>formosa</u>	338	78218,78222,78244,78251, 78252,79253,79259,79261, 79268,79271,79275,79280, 79286,79288,79301,79316, 79327,79329,79332,79336, 79339,79348,79352,79364, 79365,79369,79370,79375, 79381,79387,79388,79395, 79398,79399,79400,79403, 79406,80202,80203,80215, 80217,80218,80220,80225, 80233,80246,80251,80254, 80255,80257,80260,80262, 80265,80267
<u>Poecilia</u> <u>latipinna</u>	105	78244,79253,79259,79271, 79286,79288,79304,79316, 79321,79348,79352,79360, 79364,79387,80265
<u>Xiphophorus</u> <u>maculatus</u>	4	79288,79308,80251
Order Cypriniformes		
Family CYPRINIDAE		
<u>Notropis</u> <u>emiliae</u>	1	80263
Order Perciformes		
Family CENTRARCHIDAE		
<u>Elassoma</u> <u>okefenokee</u>	106	79259,79271,79280,79291, 79304,79316,79324,79339, 79340,79352,79364,79366, 79387,79388,79403,79409, 80220,80233,80246,80254, 80255,80260,80265

NAME	SPECIMENS	COLLECTIONS
Enneacanthus gloriosus	66	78252, 79253, 79272, 79285, 79288, 79301, 79305, 79308, 79315, 79317, 79322, 79325, 79327, 79336, 79338, 79354, 79365, 79367, 79388, 79401, 79404, 80203, 80214, 80238, 80245, 80258, 80266
Lepomis auritus	16	79261, 79280, 79285, 79329, 79338, 79341, 79364, 79366, 79367, 79385, 79404, 79406, 79411, 80219
Lepomis gulosus	5	79329, 79375, 79401, 79404
Lepomis macrochirus	39	79268, 79317, 79319, 79330, 79337, 79354, 79355, 79365, 79366, 79383, 79388, 79399, 79404, 80201, 80203, 80205, 80219, 80259, 80264
Micropterus salmoides	10	79315, 79327, 79329, 80251, 80252, 80259
Pomoxis nigromaculatus	3	80259, 80264
Family PERCIDAE		
Etheostoma parvipinne	10	79301, 79337, 79354, 79375, 79383, 79388, 79401, 79404, 80259
Order Percopsiformes		
Family APHREDODERIDAE		
Aphredoderus sayanus	11	79271, 79280, 79308, 79316, 79324, 79339, 79387, 80220, 80254, 80255, 80265
Order Siluriformes		
Family ICTALURIDAE		
Ictalurus nebulosus	1	79308
Undetermined Fish	11	78209, 78212, 78221, 78252, 79336, 79337, 79356, 80239, 80262

Chapter 2

Laboratory Biology and Host Range Studies of Parapoynx diminutalis*

by

Dr. Gary R. Buckingham, Ms. Christine A. Bennett

*This chapter presents results of a biological control program being conducted to evaluate insects to determine their potential for use in aquatic plant control. Specifically, this work involved the study of the Asian moth, *Parapoynx diminutalis*, for use against the problem aquatic plant, hydrilla. Because of its broad host specificity, it is unlikely that this insect agent would ever be used as a biocontrol agent for hydrilla. No further work is recommended on importation of this species; this is the final report upon which that decision was based.

INTRODUCTION

Aquatic Lepidoptera are of special interest as possible biocontrol agents of submersed aquatic plants. Two pyralid genera, *Nymphula* and *Parapoynx*, are cosmopolitan and together probably include over 100 species. The generic limits are not well defined and the genera are best separated by the presence (*Parapoynx*) or absence (*Nymphula*) of feathery tracheal gills on the larvae. Unfortunately, the larvae of very few species have been described and the host plants of most species are unknown.

In May 1979, Mr. Russell Theriot and Dr. Dana Sanders, U.S. Army Engineer Waterways Experiment Station (WES), observed dead moths on the water surface and larval damage and cases on hydrilla in Gatun Lake, Panama. They collected infested stems from which one male *Parapoynx rugosalis* Moeschler emerged. This species is native to the Caribbean and has been reported from Puerto Rico, Guyana, and French Guiana (Balciunas and Center 1981). Its native host plant(s) is unknown. Hydrilla is a recent introduction into the canal.

In order to learn more about *P. rugosalis,* Dr. Joe Balciunas, University of Florida (UF), visited the Panama Canal in May 1980. He collected larvae and, with the help of Dr. Ted Center, U.S. Department of Agriculture (USDA), conducted feeding tests with an array of aquatic plants (Balciunas and Center 1981). As a result of these tests, permission was obtained to import *P. rugosalis* into quarantine for testing against native plants. Dr. Balciunas returned to Panama in November 1980 and collected fertile females, larvae, and pupae from heavily damaged hydrilla mats and carried them to the quarantine facility at the Biological Control Laboratory, Division of Plant Industry (DPI), Florida Department of Agriculture and Consumer Services, Gainesville. Biological and host range studies, which are reported herein, were immediately initiated. Later we discovered that the species that we were testing was *P. diminutalis* Snellen, not *P. rugosalis*, and that the species tested in Panama by Balciunas and Center (1981) was probably an unidentified or undescribed species, *Parapoynx* sp., that was similar to *P. diminutalis*. Adults of *Parapoynx* sp. were collected in mass by Balciunas at the same time that he collected larvae for testing and were presumably the same species as the larvae; however, no adults were reared to confirm this. No adults of *P. rugosalis* or *P. diminutalis* were collected at that time. Newly emerged adults of *P. rugosalis* (Figure 1) are distinguished from the other two species by the straighter lines on the wings, but if the wings are worn they are difficult to distinguish. This is also true for a native U.S. species, *P. allionealis* (Walker), which is almost identical to *P. rugosalis*. *Parapoynx* sp. adults (Figure 2) differ from *P. diminutalis* (Figure 3) principally by the absence of black mottling on the wings. The larvae tested by Balciunas and Center lacked spots on the head that are present on larvae of *P. diminutalis*.

Dr. Dale Habeck, UF, collected larvae and adults on hydrilla in the Panama Canal during August 1981 and again during May and September 1982. The only species observed and collected was *P. diminutalis*. For some reason the other two

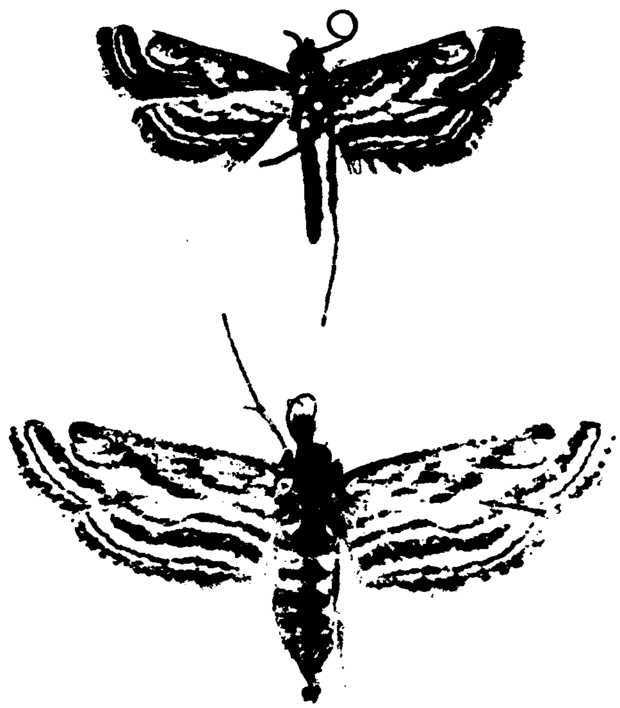

Figure 1. *Parapoynx rugosalis* Moeschler. Upper - male, lower - female (photo by D. C. Ferguson)

Figure 2. *Parapoynx* sp. female

Figure 3. *Parapoynx diminutalis* Snellen. Upper male, lower - female (photo by D. C. Ferguson)

species appeared to have disappeared from the area or were present in undetectable numbers.

Parapoynx diminutalis is an Asian moth that has been accidentally introduced into both Panama and Florida, undoubtedly through the aquarium trade. Agassiz (1978, 1981) reported that it, along with several other species of exotic aquatic moths, colonized glasshouses at an aquatic plant nursery in England and also in Denmark. Two of the species mentioned by Agassiz were North American and the others were Asian, none of which have been reported in Florida thus far. The first report of *P. diminutalis* in Florida was by Del Fosse, Perkins, and Steward (1976) who reported it feeding on hydrilla in experimental pools in Fort Lauderdale. Although it had been studied in Asia as a possible biocontrol agent of hydrilla, no shipments had been made to the United States. Balciunas and Habeck (1981) reported that its range now includes most of peninsular Florida.

Brief studies of the biology and host range of *P. diminutalis* were reported in Malaysia by Varghese and Singh (1976) and in Pakistan by Baloch, Sana-Ullah, and Ghani (1980). In Malaysia only hydrilla was an acceptable host plant when it was tested along with five other plant species. However, adults were produced in the Pakistani tests on three species of *Potamogeton* and on *Vallisneria spiralis* L. Sankaran and Rao (1972) reported collecting larvae of *P. diminutalis* in India on *Potamogeton nodosus* Poir., *Nymphaea nouchali* Burm., and *Najas indica* (Willd.) Cham. When *P. diminutalis* was first collected in Florida, limited host

range tests were conducted to determine if it was indeed polyphagous or whether it was sufficiently specific to be redistributed for control of hydrilla (Habeck, personal communication). Those tests indicated that it was polyphagous. Surprisingly, it was found only on hydrilla in field studies in Florida (Balciunas and Habeck 1981).

METHODS AND MATERIALS

All experiments were conducted at the Biological Control Laboratory, Florida Department of Agriculture and Consumer Services, Gainesville. Most experiments were conducted in quarantine.

Test insects were mostly from a laboratory colony established with eggs and larvae collected in the Rio Chagres in November 1980 near Gamboa, Panama, by J. K. Balciunas. Additional test insects were collected when needed in Orange and Lochloosa Lakes, Alachua County, Florida.

Most of the hydrilla used in the experiments and to maintain the colony were collected periodically at Manatee Springs, Levy County, Florida. Additional hydrilla was collected at Orange and Lochloosa Lakes or was grown in outdoor pools at the laboratory. The test plants in the host range studies were from various sources: field collected, laboratory pools, or aquatic plant dealers.

The laboratory colony was maintained in a large wooden cage in a greenhouse. Basically it consisted of a 2.4-m-square waterproof box that was 0.27 m deep and filled with water and hydrilla. A 1-m-high frame covered on the sides with nylon organdy was attached to the box, which sat on legs about 0.9 m high. The frame was covered on top with a translucent fiberglass panel with sleeve openings on the sides to allow access to the cage. Water was slowly added to the box so that there was a constant overflow through the organdy. In addition, the colony was reared in 3.79-ℓ jars filled with water and hydrilla and covered on top with nylon organdy. The jars were kept in a greenhouse and a temperature- and humidity-controlled rearing room. Plant material was added when necessary. The water in the jars was changed periodically and the jars bleached weekly.

Biological Studies

Individual larvae were confined in 28.4-mℓ plastic cups with lids and were examined daily to determine the instar. Measurements were made of the head capsules of these living larvae to give estimates for the instars. Exact measurements were later made with preserved larvae. All measurements are reported as $\bar{x} \pm$ SD (range, number).

Neonate larvae mortality was tested in 28.4-mℓ plastic cups with lids. Most larval rearings were made either in these small cups, in 0.95-ℓ jars, 3.79-ℓ jars, or 266-mℓ styrofoam cups. Larvae periodically were checked for condition of food and water. Counts of live larvae, dead larvae, cases, and pupae and general observations were made at this time. Larval developmental times were determined at different temperatures with 16-hr photophases in environmental chambers.

Adult longevity and fecundity were determined by confining newly merged adults in Plexiglas cylinders about 42 cm high with a 14.5 cm inside diameter. A small amount of water and hydrilla was placed in the enclosed bottom of the cylinder. The cylinder was covered on top with nylon organdy.

Host Range Studies

Oviposition tests. Oviposition tests were conducted by confining individual females in rectangular plastic boxes, 29.8 × 14 × 12 cm, containing shallow water and the stems of four test plants. There were five replicates in each test.

Larval no-choice tests. Eggs ready to hatch containing larvae with well-developed head capsules were placed in 0.95- or 3.79-ℓ jars containing stems of single plant species. Various numbers of eggs were added to the jars, which were held in temperature-controlled greenhouses. Plant material was added whenever needed and the water was changed weekly or more often if necessary. The numbers of adults and sometimes pupae produced in the jars were recorded. The plant species tested are listed in Table 1.

A test with larvae confined individually on the test plants was also conducted in the greenhouse. Eggs ready to hatch were added initially to 29.6-mℓ plastic cups but later the medium-sized larvae were transferred to 266-mℓ styrofoam cups.

Larval choice tests. Hydrilla was paired with the test plant species in 0.95-ℓ jars in the greenhouse. Ten eggs ready to hatch were added to each jar and the number of larvae were counted on each test plant after various periods.

RESULTS AND DISCUSSION OF BIOLOGICAL STUDIES

The eggs of *P. diminutalis* were deposited in masses on hydrilla plants lying at the water surface. The neonate larvae fed on the leaves and some made cases with small pieces of leaves. Second and later instars lived in tubular cases similar to those of caddisflies. Most feeding was on the leaves but the stems were also eaten. The cocoon was tightly attached to the stem. The moths emerged, mated, oviposited, and died within a few days.

Egg Stage

Description. Eggs were circular at deposition; changing to elliptical as the larva developed; dorsoventrally compressed; chorion smooth; bright yellow at deposition turning whitish as the embryo developed; transparent at hatching; size at hatching: length 0.44 ± 0.22 m (n = 10), width 0.34 ± 0.02 mm.

Deposition. The eggs (Figure 4) were deposited in masses on leaves or stems of plants lying at the water surface. They were also placed readily by the females on moist filter paper in petri dishes or on the sides of Plexiglas cylinders at the waterline. The masses varied greatly in size, with an average of 29.66 ± 19.39 eggs per mass (n = 112) for those deposited on hydrilla. Within a mass the eggs were arranged in loose rows. Most of the larvae in a mass were oriented in the same

Table 1
Summary of Greenhouse No-Choice Development Tests with Multiple Larvae of *Parapoynx diminutalis**

Test Plants	*Common Name*	*Total Eggs Tested*	*Total Number of Replicates*	*Type of Tests***	*% Adults Mean ± SD (Range)*
Nymphaea sp.† + *N. odorata*††	Waterlily	10	1	C	50
Hydrilla verticillata	Hydrilla	250	8	A, B	47.75 ± 21.7 (14-68)
Cabomba pulcherrima	Purple fanwort	98	7	B, C, G	40.7 ± 31.9 (0-90)
Hygrophila polysperma	Hygrophila	110	2	C, E	38.0 ± 45.2 (6-70)
Egeria densa	Egeria	50	2	B	34.0 ± 25.4 (16-52)
Vallisneria americana	Watercelery	160	13	C, D	27.3 ± 21.3 (0-70)
Najas guadalupensis	Southern naiad	50	2	B	24.0 ± 33.9 (0-48)
Ceratophyllum demersum	Coontail	70	7	C	22.9 ± 21.4 (0-84)
Najas minor + *N. guadalupensis*††	Slender naiad Southern naiad	50	2	B	20.0 ± 5.6 (16-24)
Zanichellia palustris + *Eleocharis* sp.††	Horned pondweed Dwarf spikerush	60	3	D	16.6 ± 28.8 (0-50)
Eleocharis sp.	Dwarf spikerush	100	2	A	13.0 ± 1.4 (12-14)
Myriophyllum spicatum	Eurasian watermilfoil	120	4	A, C	7.5 ± 8.6 (0-20)
Mayaca fluvialis	Bogmoss	100	2	A	5.0 ± 4.2 (2-8)
Ruppia maritima	Widegeongrass	150	4	A, B	4.5 ± 5.2 (0-12)
Polygonum sp.	Smartweed	50	1	A	4.0
Myriophyllum heterophyllum	Broadleaf watermilfoil	150	4	A, B	4.0 ± 4.6 (0-8)
Nymphaea odorata	Fragrant waterlily	250	6	A, B	0.7 ± 1.6 (0-4)
Utricularia foliosa	Bladderwort	50	2	B	0
Utricularia biflora	Bladderwort	50	2	B	0
Proserpinaca palustris	Mermaidweed	20	2	C	0
Oryza sativa L. 'Saturn'	Saturn rice	220	3	C, G	0
Nuphar sagittifolium	Spatterdock	210	3	C, G	0
Nitella sp.	Nitella	20	2	C	0
Salvinia rotundifolia	Common salvinia	100	2	A	0
Lemna minor	Common duckweed	100	2	A	0
Bacopa caroliniana	Bacopa	179	4	A, H	0
Azolla caroliniana	Waterfern	150	4	A, B	0
Nuphar advena	Spatterdock	170	4	A, D	0
Nymphoides aquaticum	Bananalily	200	4	A	0
Pistia stratiotes	Waterlettuce	150	4	A, B	0
Sagittaria subulata complex	Arrowhead	130	7	C, D	0
Sagittaria isoeteformis	Arrowhead	60	3	D	0
Potamogeton illinoensis	Illinois pondweed	120	6	D	0
Marsilea sp.	Marsilea	100	2	A	0
Isoetes sp.	Isoetes	100	2	A	0
Echinodorus sp.†	Burhead	120	4	A,C	0
Nasturtium officinale	Watercress	100	2	A	0
Limnobium spongia	Frogbit	70	4	B,C	0

* All tests were initiated with eggs that had well-developed larvae visible inside; replicates were initiated when larvae were available from November 1980 through May 1981.

** A - 50 eggs/0.95-ℓ jar; B - 25 eggs/0.95-ℓ jar; C - 10 eggs/0.95-ℓ jar; D - 20 eggs/3.79-ℓ jar; E - 100 eggs/0.95-ℓ jar; F - 200 eggs/3.79-ℓ jar; G - 8 eggs/0.95-ℓ jar; H - 29 eggs/0.95-ℓ jar; I - 5 eggs/0.95-ℓ jar

† Ornamental species from aquatic plant dealer.

†† Test initiated with the first species, but the second species was substituted when the first was no longer available.

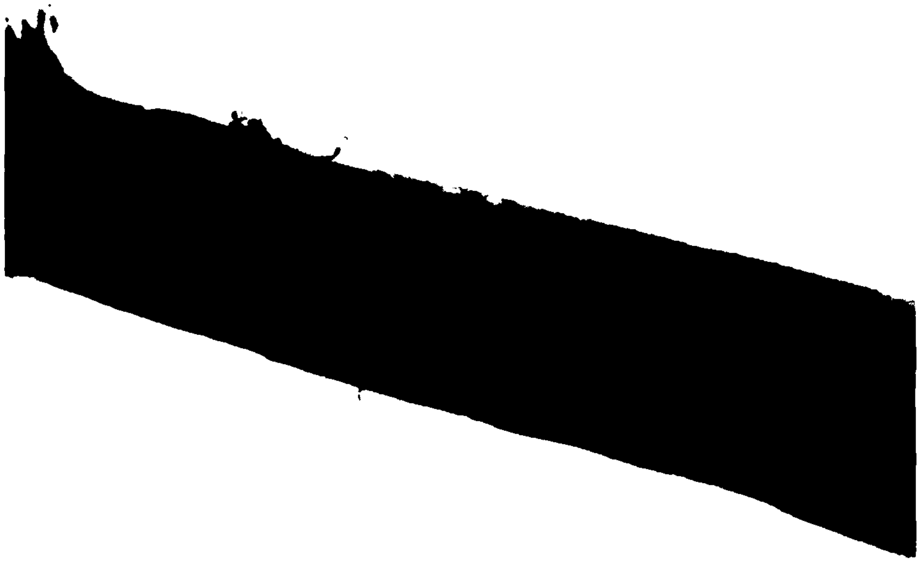

Figure 4. Larvae of *P. diminutalis* hatching from eggs on a hydrilla stem

direction. However, often the larvae in a row or portions of rows were oriented in the opposite direction, indicating that the female shifted while ovipositing or changed the direction of her ovipositor.

Development. *The first sign of development was a change of color from yellow* to whitish. The position of the head was indicated initially by two small dark eyespots near one end. The head later darkened to light brown with dark mandible tips. The curled embryo developed lying on its side and within a few hours prior to hatching it actively moved within the egg. The time of development was 4-6 days at 28°-30°C. Eggs normally developed underwater but those held outside of water on moist filter paper also developed.

Larval Stage

Description. There are seven instars: I° - whitish almost transparent; no tracheal gills; orange malpighian tubules visible; one pair of long anal setae (0.20-0.22 mm); smaller setae in longitudinal rows dorsally and along each side; head capsule light brown with dark brown ocelli and epicranial suture; mandibles reddish; light brown pronotal shield about equal to width of head; length of neonates about 0.95 mm, width of head capsule 0.21 ± 0.01 mm, range = 0.20-0.24, n = 18. II°-VII° - whitish to yellowish just before pupation; trachael gills present along each side, number increasing in each instar; head capsule light brown with scattered small dark spots (Figure 5) which are not present on that of I° instar, length increasing with each instar to 11.45 ± 2.5 mm (7.52-14.08, 7) at maturity; instars best separated by width of head capsule: II° - 0.29 ± 0.02 (0.26-0.30, 5), III° -0.42 (1), IV° - 0.62 ± 0.03 (0.60-0.66, 8), V° - 0.81 ± 0.51 (0.75-0.90, 16), VI° - 1.02 ± 0.02 (0.98-1.06, 30), VII° - 1.15 ± 0.04 (2.20-2.30, 18).

Figure 5. Mature larva of *P. diminutalis* on hydrilla

Development. The duration of the larval stage at 26.7°C was 21-35 days. Although the number of days for each instar were not determined exactly, they were about: I° - 4 days, II° - 3, III° - 3-5, IV° - 2-3, V° - 2-5, VI° - 3-8, VII° - 3-9. The rate of development was related directly to temperature. The durations of the larval stage at various temperatures were: 22.2°C, 32.2 ± 7.3 days (23-48, 29); 23.3°-25.6°C, 28.0± 2.8 days (21-37, 11); 26.7°C, 27.1± 3.8 days (21-35, 17); 30.6°C, 20.8 ± 4.1 days (17-31, 20).

Behavior. The newly emerged larvae (neonates) were active crawlers and, although some began feeding immediately, many wandered about the containers before settling on plants. It was not unusual to find that some had crawled out of containers that were not covered. These neonates fed on the leaf both by scraping the surface so that the leaf was transparent and by eating portions of the leaf. Most fed without a case but some made a simple case by cutting a small (ca. 2 mm long) piece of leaf and attaching it to the leaf surface. Some second instars fed without a case but most made simple cases. All later instars made tubular cases by cutting leaves or stems and tying them together (Figure 6). The cases were similar to those of some caddisflies. The larvae fed on the leaves from these cases which they carried with them. However, larvae were often observed at night in the containers crawling without cases. One night many larvae were observed outside their cases clustered together near the surface in an aerated jar that had a fluorescent light lying on top. Whether this was a positive response to light or just to the heat or some other factor was not determined. Leaves were consumed most readily; however, portions of the stem were also consumed during heavy feeding.

Mortality. Although the neonates often crawled out of the containers, they were not able to develop outside water. All (30) died within 1 hr in dry conditions

Figure 6. Larval cases of *P. diminutalis* constructed of hydrilla leaves and stem

at 22.2°C. They survived in moist containers for 2.25 ± 0.6 days (1.3-3, 30) without hydrilla and for 4.3 ± 1.2 days (3-5, 30) with hydrilla. In the greenhouse at 14.4°-26.7°C, 42 percent survived 6 days in water without hydrilla but none survived 14 days.

Early larval mortality (within first 2 weeks) was greater than or equal to 50 percent in 10 of the 21 tests where individual larvae were monitored. There were no obvious causes for this; however, mortality was generally less when eggs ready to hatch containing active larvae were transferred rather than neonates. Early instar larval mortality in greenhouse experiments was similar to that in laboratory and temperature cabinet experiments; however, later instar mortality was less and more adults were produced in the greenhouse. Aeration of the water did not improve survival in the small containers with individual larvae, but it did appear to do so in the large jars with multiple larvae and many hydrilla stems. The dissolved oxygen in a gallon jar about half-filled with hydrilla stems and completely filled with water dropped to 1.4 ppm without light on the jar.

Cannibalism was not observed, though mortality was generally higher when large numbers of larvae were present, especially in the early instars.

Researchers in Florida occasionally have damaging infestations of *P. diminutalis* in their experimental pools and wish to eliminate the larvae. A

commercial preparation of *Bacillus thuringiensis,* Dipel Hg, at about 10 percent of the dosage recommended as a garden spray, produced 80 percent mortality within 4 days compared to no mortality in the controls. The surviving larvae in the Dipel jars had not fed and were dead when observed at 10 days. This microbial pesticide is not registered for aquatic environments, so its use is limited to experimental pools.

Pupal Stage

Description. The pupa was similar to those of other species of *Parapoynx.* It was narrow, elongate, with three distinct spiracular tubercles along each side and two strong dark setae on top of the head. The female pupa was differentiated most easily from that of the male by the length of the antennae. The female's antennae ended in the 4th abdominal segment just before the wing tips, whereas the male's antennae exceeded the wing tips and ended in the 5th abdominal segment. The female pupa was also larger than the male pupa. The abdomen expanded in length as the pupa darkened prior to emergence. The pupal measurements were: female - length 7.82 ± 0.34 mm (7.14-8.33, 11), width 2.09 ± 0.10 (1.96-2.30, 11), width including spiracles 2.31 ± 0.09 (2.21-2.47, 11); male - length 6.63 ± 0.20 (6.12-6.80, 10), width 1.67 ± 0.11 (1.45-1.79, 10), width including spiracles 1.84 ± 0.11 (1.62-1.96, 10). The lengths of darkened pupae were: female - 8.97 ± 0.05 (8.93-9.01, 4); male 7.9 (1).

The pupa was enclosed in a white silken cocoon (Figure 7) that was firmly attached parallel to the stem. Some cocoons were attached at only one end of the cocoon so that they were perpendicular to the stem. The cocoons were covered with leaves as were the larval cases. The pupae obtained oxygen through holes in the cocoons that corresponded with one to four excavations of various sizes made

Figure 7. Cocoon of *P. diminutalis* on hydrilla stem

in the stems by the larvae. Lekic (1970) has illustrated similar holes in the cocoons of *P. stratiotata,* which attack Eurasian watermilfoil in Europe. The size of the cocoons varied but generally the female's cocoons were longer than the male's. The cocoon lengths were: female - 11.50 ± 1.19 mm (9.52-12.53, 9); male - 9.47 ± 1.11 (8.35-11.69, 10).

Development. The mature larva (prepupa) remained immobile for 1.2 days inside the cocoon before pupating. The duration of the pupal stage at 26.7°C was from a minimum 4-5 days to a maximum 6-10 days (n = 11). It was 6-7 days for 10 pupae checked daily. Distinct color changes were associated with development. The newly formed pupa changed from white to yellow. The eyes darkened to red and then dark brown. The entire pupa was dark and the wing pattern was visible shortly before emergence. The pupa actively moved its abdomen when disturbed during the first few days but it was immobile during the last few days. If the stem section was only a few centimetres long or if it became waterlogged, the pupa died. Pupae developed normally when removed from the cocoon to moist sphagnum or filter paper in closed containers. From 17 pupae removed from cocoons to sphagnum, 14 adults emerged compared to 8 adults that emerged from 57 pupae left in the cocoons on stems, 10-12 cm long, in test tubes.

Adults

Description. The adults were white with light brown or tan stripes on the wings and body. Variable amounts of black scales masked portions of the stripes. The female (Figure 8) had a wider wingspread, more pointed forewings, a more robust abdomen, and relatively shorter antennae than the male (Figure 9). The wing patterns of both sexes were similar although the male generally had more black on the wings. In both sexes the amount of black generally varied inversely with the temperature at which the larva was reared. The species of host plant also

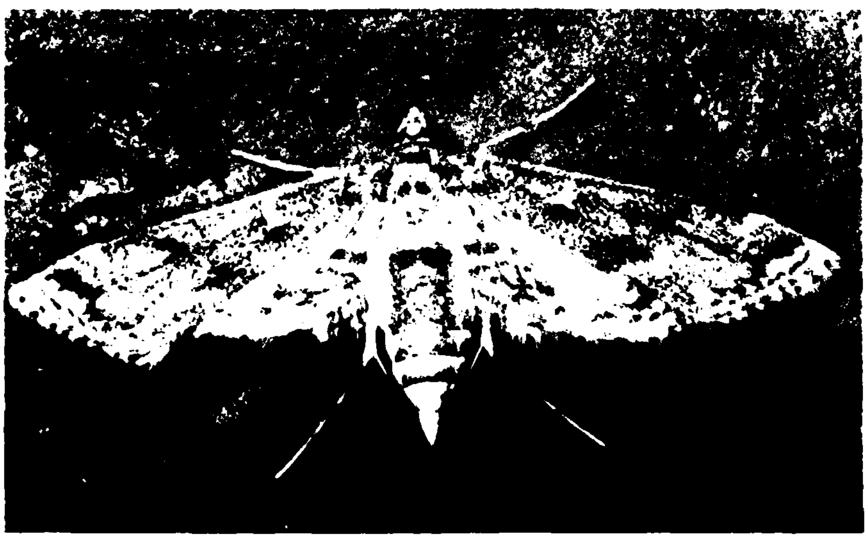

Figure 8. *Parapoynx diminutalis* female

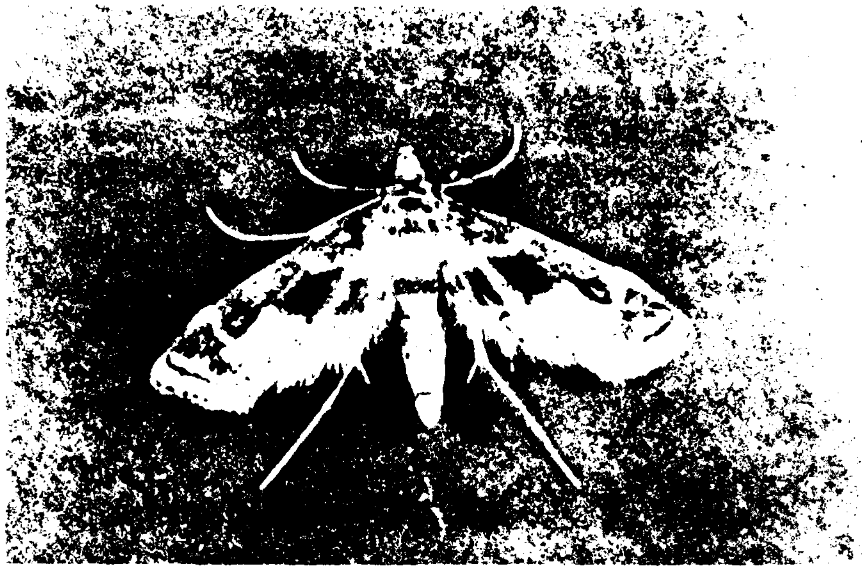

Figure 9. *Parapoynx diminutalis* male

appeared to influence the amount of black. Both sexes generally held the wings outspread and pressed to the substrate while sitting. If disturbed, however, they often flew and landed with the forewings facing backward and covering the hindwings but not overlapping the body.

Development and longevity. The time required for development from neonates to adults varied greatly with temperature but not with sex. The female mean was generally higher than the male's, but it was never significant. The developmental times were: 22.2°C, 44 ± 5.1 days (37-58, 21); 30.6°C, 27 ± 3.7 (25-38, 16); 33.3°C, 25.9 ± 4.1 (22-27, 12); 33.3°C:22.2°C* (LD 16:8), 21.5 ± 2.2 (19-26, 27); 36.1°C, 21.1 ± 2.8 (17-26, 20). The differences in means were significant except between those at 30.6° and 33.3°C and at 33.3°C:22.2°C and 36.1°C. These latter means were not significantly different. Development was favored by lowering the nighttime temperature similar to the natural conditions. No adults were obtained at 14°C and 38°C. A few adults (15 percent) were obtained at 19.4°C, 59.8 ± 3.1 days (58-66, 6).

Although the complete developmental time from newly deposited egg to adult was not determined, it should be about 29-44 days at 30°C. This figure was obtained by adding the range for egg development, 4-6 days at 30°C, to the range for larval-pupal development, 25-38 days at 30.6°C.

There was no significant difference in the mean longevity of males and females. The mean longevities at 22.2°-25.6°C in greenhouses were: males, 5.1 ± 2.2 days (1-10, 24); females, 6.3 ± 3.1 (2-17, 20). At a constant 24.4°C in a temperature cabinet, they were: males, 4.0 ± 1.4 (3-6, 6); females, 4.3 ± 0.6 (4-5, 3).

Fecundity. Newly emerged females reared on hydrilla at different temperatures were dissected to determine their egg complements. The results of these

* Alternating light-dark (LD) temperatures.

dissections were: 19.4°C, 119.5 ± 64.0 eggs/female (25-167, 4); 22.2°C, 196 (196, 1); 25.0°C, 163.0 ± 116.0 (51-283, 3); 26.7°C, 343.6 ± 87.2 (205-423, 7); 30.6°C, 231.5 ± 59.1 (130-297, 11); 30.6°C:22.2°C (LD 16:8), 313.4 ± 58.5 (218-419, 19); 33.3°C, 263 ± 52.9 (194-334, 7); 33.3°C:22.2°C (LD 16:8), 332.7 ± 86.9 (234-483, 7); 36.1°C, 213.0 ± 69.1 (143-337, 7); 36.1°C:30.6°C (LD 16:8), 216.5 ± 50.1 (130-289, 12). The females were significantly more fecund when the larvae were reared at the constant temperature of 26.7°C or at the alternating light-dark temperatures of 30.6°C:22.2°C and 33.3°C:22.2°C. Those reared at a constant 33.3°C were intermediate and were not significantly different from the preceding three regimes nor from the 25.0°C, 36.1°C, and 36.1°C:30.6°C regimes. In earlier oviposition experiments, 26 mixed females that had been reared at temperatures from 21.1°C to 26.7°C deposited a mean 222.9 ± 140.6 eggs/female (3-524, 26). Four of the females deposited less than 30 eggs each and, if their totals are disregarded, the mean for the remaining 22 females was 261.2 ± 116.3 (108-524). Fourteen of these 22 females were dissected at death and had a mean 5.3 ± 13.2 eggs/female (0-45) remaining in their ovaries. Apparently under our laboratory conditions most females that were stimulated to oviposit more than a few eggs deposited all or most of their eggs before dying.

Behavior. The adults began emerging in a large greenhouse cage within approximately 30 min after dusk and began flying about 30 min later. They sat on the emersed hydrilla stems, the sides of the cage, or the water surface while their wings expanded. If disturbed at this time, they ran quickly across the hydrilla or the water surface. Even though unable to fly during these first few minutes, they would not be easy prey for all predators. Mating was not observed until about 3 hr after dusk, although females were observed ovipositing within the first hour after dusk. Apparently the ovipositing females were at least 1 day old and had already mated. Mating pairs rested facing in opposite directions for at least 30 min, but the maximum length of mating was not determined. The ovipositing female sat above the water surface and inserted her ovipositor into the water to oviposit on leaves or stems as described in the section on the egg stage. Eggs were also placed occasionally just above the water surface. No females in our experiments oviposited before the second night, although they apparently mated the first night. There would probably be heavy mortality of these females both in Panama and Florida before they could oviposit since the hydrilla mats extend considerable distances from shore. In their native habitats they probably evolved in smaller water bodies with extensive protective vegetation on the shore nearby.

Adults that had been held ' . a refrigerator for several days without free water were observed on two occasions apparently imbibing water from the wet surface of leaves after their removal to room temperature. The proboscis was short but apparently functional. There was no difference in the longevity of adults held with sugar water versus those held with water.

Adults were attracted to both incandescent lights and ultra-violet blacklights placed on the side of the greenhouse cage, but they did not respond to the red light which allowed them to be observed without disturbance.

Field observations. Populations of *P. diminutalis* were present in several

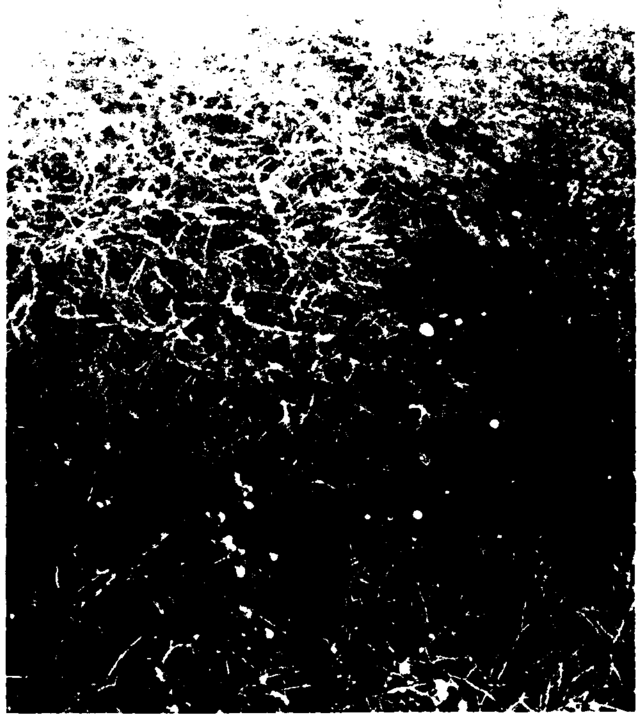

Figure 10. Surface stems of hydrilla defoliated by *P. diminutalis* larvae at Lochloosa Lake, Florida

waterways near Gainesville as previously reported by Balciunas and Habeck (1981). Noticeable larval damage (Figure 10) was observed in Orange and Lochloosa Lakes from about August to November during 1981 and 1982. The amount of damage varied among the mats but occasionally as many as 75 percent of the surface stems of a mat were leafless. The moth populations appeared to be heavily disrupted by the winter decline of hydrilla and probably by low water temperatures. Herbicide spraying may have also been a factor since areas heavily attacked one year were often sprayed the next. Although the moth populations have not controlled hydrilla to any noticeable extent, they have at least added stress to the hydrilla plants. This stress may make the plants more susceptible to native diseases, as has been observed with waterhyacinth and its weevils, or to herbicides. Other species of submersed plants besides hydrilla have been searched for *P. diminutalis* larvae in locations where the moth occurs. Immatures have been found near Gainesville only on *Potamogeton illinoensis* (eight larvae), *Ceratophyllum demersum* (one pupa), and *Najas guadalupensis* (two larvae). In the area near Gainesville, *P. diminutalis* apparently attacks almost exclusively hydrilla.

RESULTS AND DISCUSSION OF HOST RANGE STUDIES

The host range studies were initiated to determine if "*P. rugosalis*" was safe for introduction. When the specimens were later identified as *P. diminutalis*, not *P. rugosalis*, the studies in progress were continued in order to more completely define the host range of this introduced species.

Oviposition Tests

When hydrilla was present with Brazilian elodea (see Table 1 for scientific names), Illinois pondweed, and southern naiad, there were no significant differences in the number of eggs deposited on the first three species. No eggs were placed on southern naiad; however, in other nonreplicated tests, that species received more eggs than hydrilla. When hydrilla, fanwort, dwarf arrowhead, and watercelery were compared, no eggs were placed on dwarf arrowhead, but there were no significant differences in the numbers of eggs placed on the other three species. In another test there were significantly more eggs placed on coontail than on hydrilla and spikerush, but not more than on Eurasian watermilfoil. There were no significant differences among the latter three species. When coontail was present with fanwort, Illinois pondweed, and Brazilian elodea, there were no significant differences. These results, along with the results of additional nonreplicated trials, indicate that at least in small containers the females do not prefer hydrilla over other potential hosts or else do not discriminate.

Larval No-Choice Tests

The results of greenhouse tests with multiple larvae confined to jars of single plant species are summarized in Table 1. Complete development to adults took place on 14 plant species plus on 3 combinations that included an additional 3 species. The highest percentage of adults (90 percent) was produced in one replicate of fanwort but the highest mean was on hydrilla. The single jar that was initiated with an Asian waterlily and then completed with a native waterlily when the first was no longer available produced many more adults than those with only the native waterlily. Waterlily was recorded as a natural host in India by Sankaran and Rao (1972); however, no larvae have been found on waterlily in Florida. No adults were produced on Illinois pondweed in these jars even though larval feeding readily destroyed the plants. Unfortunately, we did not have an abundance of plants of this species and the complete lack of successful development may have been due to plant condition. Cocoons were formed but the pupae did not survive on the damaged plants. This species was a host in other tests. Pupa[1] survival was also low on dwarf spikerush and Eurasian watermilfoil. Larvae fed and developed on the bladderworts but the plants did not provide air to the pupae. In the two replicates on *U. foliosa*, 76 and 85 percent of the larvae reached medium size and 12 percent in one replicate pupated, but unsuccessfully. No larvae pupated in the replicates with *U. biflora* but 76 and 100 percent reached at least medium size. In two replicates on rice, 40 percent in each reached medium size but none pupated.

The results of a greenhouse test with larvae confined individually on the test plants are presented in Table 2. The percentages of adults produced on the test plants were mostly equal to or greater than the means in the previous tests with multiple larvae. The greatest difference was with Illinois pondweed on which 47.4 percent of the larvae produced adults compared to none in the tests with multiple larvae. When the larvae pupated in these individual containers, the pondweed remained in good condition providing air to the pupae. A similar increase in survival was obtained with widgeongrass. The larval-pupal developmental period was similar on most of the plant species except on watercelery and spikerush which had significantly longer periods than hydrilla and some of the others. In another test, however, the developmental period on spikerush was similar to that on hydrilla.

Many tests were initiated with large numbers of larvae confined individually in small cups placed at different temperatures in environmental chambers. Mortality was extremely high in most of these tests for unknown reasons. In one test at 26.7°C with 20 larvae per plant species, 35 percent of the larvae produced adults on fanwort, 20 percent on coontail, 10 percent on hydrilla, 5 percent on Brazilian elodea, 5 percent on slender naiad, 0 on salvinia, and 0 on waterlettuce.

Table 2
Results of a Greenhouse No-Choice Development Test with Individual Larvae of *Parapoynx diminutalis**

Test Plant	*Common Name*	*Total Eggs Tested*	*% Pupae*	*% Adults*	*Larval-Pupal Developmental Periods (Days)*** *Mean* ± SD (Range, N)
Myriophyllum spicatum	Eurasian watermilfoil	19	63.2	63.2	32.3 ± 4.7 (29-43, 12)
Cabomba sp.	Fanwort	19	63.2	57.9	33.3 ± 4.9 (27-41, 11)
Egeria densa	Egeria	19	57.9	57.9	44.7 ± 6.4 (37-54, 11)
Najas guadalupensis	Southern naiad	19	63.2	52.6	38.8 ± 3.3 (34-43, 10)
Potamogeton illinoensis	Illinois pondweed	19	57.9	47.4	33.4 ± 2.7 (29-37, 8)
Hydrilla verticillata	Hydrilla	19	57.9	47.4	35.0 ± 3.4 (29-41, 9)
Hygrophila sp.	Hygrophila	19	47.4	47.4	33.8 ± 1.4 (33-37, 8)
Vallisneria americana	Watercelery	20	50.0	45.0	42.8 ± 3.6 (36-47, 9)
Ruppia maritima	Widgeongrass	19	42.1	42.1	42.0 ± 7.0 (33-49, 8)
Myriophyllum heterophyllum	Broadleaf watermilfoil	19	31.6	26.3	43.8 ± 8.7 (34-57, 5)
Eleocharis sp.	Spikerush	19	36.8	15.7	49.7 ± 3.8 (47-59, 3)
Ceratophyllum demersum	Coontail	19	10.5	10.5	41.0 ± 0 (2)
Mayaca fluvialis	Bogmoss	19	5.3	5.3	50.0 (1)

* Mature eggs placed initially in 29.6-ml plastic cups; medium-sized larvae transferred to 266-ml styrofoam cups.

** Greenhouse temperatures, 24° ± 1°C, except one night when the minimum was 14.4°C.

When groups of 10 medium-sized larvae were transferred from the rearing containers with hydrilla to jars containing either hydrilla or a test plant, they produced adults as follows: hydrilla (4 jars) 60-90 percent adults, dwarf spikerush (2) 40 percent each, parrotfeather (*Myriophyllum aquaticum* (Vell. Verdc.)) (2) 20-30 percent, watercress (1) 10 percent, mermaidweed (1) 20 percent, unidentified grass (1) 0. Apparently the host range for larval development is broader for medium-sized larvae than for young larvae.

Larval Choice Tests

Plants that had been exposed to females in the oviposition tests were placed together without disturbing the eggs. When the larvae were medium sized, they and the total attached cases were counted on each plant species. The results were as follows: frogbit, 0 larvae, 0 cases; spatterdock, 0 larvae, 0 cases; Illinois pondweed, 0 larvae, 13 cases; Brazilian elodea, 35 larvae, 63 cases; hydrilla, 16 larvae, 23 cases; southern naiad, 10 larvae, 3 cases; coontail, 0 larvae, 8 cases.

When hydrilla was paired with another plant species in the greenhouse and exposed to larvae for 12 days, there were significantly more cases on hydrilla than on fanwort and Illinois pondweed but significantly less than on Eurasian watermilfoil and coontail. There was no difference between hydrilla and dwarf spikerush. The cases were not opened to count the medium-sized larvae.

Additional pair tests were initiated with the mature eggs in the greenhouse, and the larvae on each plant species were counted at 6 days and again at 13 days. There were significantly more larvae on hydrilla than on the following: fanwort, Illinois pondweed, and dwarf spikerush on both days, Brazilian elodea at 6 days, and coontail at 13 days. There were no differences with the latter two species on the other days nor with southern naiad and Eurasian watermilfoil on both days. Other pair tests were checked on various days. Hydrilla had more larvae than hygrophila (7, 14 days), southern naiad (7, 14 days), watercelery (6, 13 days), fanwort (10 days, not 4 days), and Brazilian elodea (14 days, not 21 days), but not more than coontail (4, 10 days) and fanwort (12, 19 days, 2nd replicate).

The results of these choice tests were variable but generally hydrilla was preferred. This may explain why *P. diminutalis* has been found mostly on hydrilla in the field. The other plant species that appear to be the best candidates for attack by *P. diminutalis,* based upon both the choice and no-choice tests, are Eurasian watermilfoil and Brazilian elodea. Coontail, southern naiad, and fanwort are also good candidates and, in fact, larvae have already been found in the field on the first two species. Larvae also have been found in the field on Illinois pondweed and, even though pondweed supports development, the larvae do not accept it as readily as the other species.

CONCLUSIONS

Parapoynx diminutalis appears to be well established both in Panama and Florida. Its potential to extensively damage or control hydrilla is much greater in Panama because of the warm climate. In Florida, at least near Gainesville, the

cool water temperatures in autumn and winter and the decline in hydrilla reduce the larval populations to almost undetectable levels. The populations near Gainesville rebound quickly, however, so that by late summer the defoliation of surface hydrilla stems is often extensive. If eggs or adults were released when hydrilla reached the water surface, perhaps the population of *P. diminutalis* would increase fast enough to at least slow the surface growth of hydrilla. Extensive defoliation might also make the plants more susceptible to herbicides.

Surprisingly, *P. diminutalis* has been found almost entirely on hydrilla in the field. Only a few individuals have been found on other plant species even though the populations of those other plant species were large. The host range studies, however, showed that development was possible on a wide range of hosts. Perhaps as *P. diminutalis* extends its range in Florida and increases in abundance, other plant species, for example Eurasian watermilfoil or Brazilian elodea, will be attacked. In any case, these studies indicate the difficulty in adequately predicting that an insect is unsafe for introduction based upon polyphagy in laboratory experiments. The broad "enforced" host range and the apparent lack of survival at cold temperatures suggest that *P. diminutalis* might be able to be manipulated for control of other plant species in cold climates. For example, releases might be made in a waterway infested with one or several host plants and, even if the larvae destroyed those plants during the summer, winter would eliminate the *P. diminutalis* population. Additional temperature experiments should be conducted if this technique is ever considered.

ACKNOWLEDGEMENTS

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Chapter 3

Evaluation of Chemicals for Aquatic Plant Control

by

Dr. Thai K. Van, Dr. Kerry K. Steward

INTRODUCTION

Background

It is widely recognized that aquatic plants are necessary to the maintenance of all other forms of aquatic life and have various favorable effects on the aquatic environment. Excessive aquatic plant growths, however, have a detrimental effect on water quality and use. They interfere with flow and utilization of water for irrigated agriculture; cause severe problems to navigation in streams and inland waterways; limit recreational activities such as fishing, swimming, and boating; present health hazards by providing breeding sites for mosquitoes and other insect pests; and depress values of real estate along canals, streams, and lakes.

Management of aquatic plants is primarily accomplished with herbicides; however, the number of chemicals registered nationally for aquatic use and available to the water manager has decreased dramatically in recent years.

The reduction in the number of available chemicals is due to the loss of registration of older chemicals, usually because of adverse environment impact, and to the reduction in number of new chemicals being developed by industry. With the assistance of government, industry, and university laboratories, the search for new chemicals and new technology should be expanded.

Safer and more effective herbicides and growth regulators need to be developed for selective removal and for inhibition of regrowth of noxious aquatic species at a lower cost. Techniques of formulating chemicals used in water which will reduce environmental impact, as well as increase efficacy, also need to be evaluated.

The evaluation of controlled release (CR) herbicide formulations for use in aquatic plant management has been one of the major objectives of our program during the last few years. The concept of CR formulations is to allow a prolonged exposure of the target plants to a sustained low concentration of a given herbicide. The effective use of CR herbicides appears to hold great potential for long-term management of aquatic plant growth with much less chemical required for the same period of activity.

Hydrilla (*Hydrilla verticillata* Royle) is presently one of the most troublesome aquatic weeds in many southeastern states and is spreading at an alarming rate to other areas of the country. One major problem encountered in controlling hydrilla is the fast regrowth of the plant from vegetative propagules, i.e., tubers and turions. Hydrilla tubers are buried in the hydrosoil and are therefore immune to conventional control techniques. For extended hydrilla control, it would be necessary to find chemicals that are translocated to regenerative tissues and inhibit regrowth, or chemicals that could be applied preemergence and attack emerging new growth.

Dichlobenil (2,6-dichlorobenzonitrile) has been shown to have herbicidal activity toward germinating seedlings of many weed species. The effect of this herbicide on aquatic plants was first reported by Barnsley (1960) who found that

Salvinia auriculata Aubl. exhibited severe sprout inhibition after treatment of 1 ppm dichlobenil. Later studies showed high activity of dichlobenil against many other aquatic species (Walker 1964; Hiltibran 1966; Taylor 1968; Weldon, De Rigo, and Blackburn 1968; Durden and Blackburn 1972). In recent field tests conducted by Steward (1980), hydrilla regrowth was controlled over 48 months in one of the three replicates treated with 11 kg/ha dichlobenil. Regrowth was associated with disappearance of the herbicide in the water. Various studies have been conducted in our laboratory during FY 82 to evaluate the potential of several CR formulations of dichlobenil to maintain inhibitory levels of the chemical in water for long-term control of hydrilla regrowth from propagules.

Fluridone (1-methyl-3-phenyl-5-[3(trifluoromethyl)phenyl] - 4(1H)-pyridinone) is a relatively new preemergence herbicide for use on cotton (Waldrep and Taylor 1976). The chemical was later found to possess high activity against new growth of hydrilla and other aquatic vascular plants at low application rates (Arnold 1979). Results of our studies with ^{14}C-fluridone, however, indicated a sigmoid-shape uptake curve by hydrilla, with very slow uptake rates during the first few days after treatment. The slow initial uptake may present a problem in the control of submersed aquatic plants with this herbicide in flowing waters, such as in irrigation and drainage canals. One logical approach to improving the uptake characteristics of fluridone is by incorporating the herbicide in a CR formulation. The CR formulation would be designed to provide adequate plant contact through timed release of the herbicide, thereby increasing the chances for plant uptake. During FY 82, a monolithic fiber containing fluridone was evaluated for control of hydrilla regrowth in flowing water.

The evaluation of various CR formulations of 2,4-D for use on watermilfoil (*Myriophyllum spicatum* L.) has also been a high-priority item of our program. The uptake and translocation of 2,4-D in plants have been reviewed extensively (Richardson 1977). At relatively low doses, 2,4-D is translocated throughout the plant tissues and is therefore able to kill the entire plant.

A protocol for evaluating CR herbicide formulations has been developed and involves determinations of: (a) chemical release rates; (b) stability of the released chemicals (degradation rate); (c) constancy of chemical release from the formulation (reliability); and (d) efficacy of the formulation in managing or eliminating aquatic plant problems. All four of the above evaluation phases are initially conducted in the laboratory. Confirmation of findings from the last two phases is attempted in outdoor studies conducted in large aquaria under environmental conditions more closely approximating those in the field.

The major emphasis of our investigations on this project has been to implement the protocol for evaluating various CR herbicide formulations provided us by different cooperating formulators. Progress on the implementation of the protocol as well as the results of the conventional herbicide evaluation program are discussed in this report.

Aquatic weeds treated in FY 1982 are:

Alligatorweed	*Alternanthera philoxeroides* (Mart.) Griseb.
Cabomba	*Cabomba caroliniana*, var. *multiparita*
Chara	*Chara* spp.
Coontail	*Ceratophyllum demersum*, L.
Duckweed	*Lemna* spp.
Egeria	*Egeria densa* Planch.
Hydrilla	*Hydrilla verticillata* Royle
Hygrophila	*Hygrophila polysperma* (Roxb.) Anderson
Lemon bacopa	*Bacopa caroliniana* (Walt.) Robins.
Sago pondweed	*Potamogeton pectinatus* L.
Southern naiad	*Najas guadalupensis* (Spreng.) Magnus
Torpedograss	*Panicum repens* L.
Waterhyacinth	*Eichhornia crassipes* (Mart.) Solms
Waterlettuce	*Pistia stratiotes* L.
Watermilfoil	*Myriophyllum spicatum* L.

The names and sources of chemical compounds evaluated in FY 1981 are listed in Table 1.

Table 1
Names and Sources of Chemicals Evaluated in Fiscal Year 1981

Common Name	*Chemical Name*	*Source*
AC 214 AC 925	Confidential	American Cyanamid Co. P.O. Box 400 Princeton, N. J. 08540
Casoron G Casoron GSR	Slow release formulation of dichlobenil	Duphar B.V., Crop Protection Division, P.O. Box 632 1000 AP Amsterdam, Netherlands
Cide Kick	d-limonene and an unspecified mix of emulsifiers	JLB International Chemicals, Inc. P.O. Box 457 Hialeah, Fla. 33010
Copper EDA	Copper-Ethylenediamine Complex	Sandoz, Inc., Crop Protection Komeen 480 Camino Del Rio South San Diego, Calif. 92108
Dicamba	3,6-dichloro-o-anisic acid	Vesicol Chemical Corp. 341 East Ohio St. Chicago, Ill. 60611
Dichlobenil	2,6-dichlorobenzo-nitrile	Thompson Hayward Chemical Co. P.O. Box 2383 Kansas City, Kan. 66110
Dichlobenil-alginate granules	Controlled release formulations of dichlobenil	Southern Regional Research Center USDA, ARS, P.O. Box 19687 New Orleans, La. 70179
D1 D2	Controlled release formulations of dichlobenil	Unique Technologies, Inc. 71 S. Cleveland Ave. Mogadore, Ohio 44260
Diquat	6,7-dihydrodipyrido (1,2-a:2′,1′c) pyrazinediium dibromide	Chevron Chemical Co. Ortho Division 940 Hensley St. Richmond, Calif. 93710

(Continued)

Table 1 (Concluded)

Common Name	*Chemical Name*	*Source*
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	E.I. DuPont de Nemours & Co. Biochemicals Department Wilmington, Del. 19898
DPX-5648	Methyl 2-[(4,6-di-methyl-2-pyrimidinyl) aminol-carbonyl]amino sulfonylbenzoate	E.I. DuPont deNemours & Co. Wilmington, Del. 19898
Endothall	Salts of 7-oxabicyclo (2.2.1)heptane-2,3-dicarboxylic acid	Pennwalt Corp. Agricultural Chemical Division 1630 East Shaw Ave. Fresno, Calif. 93710
Fenac	Salts of 2,3,6-tri-chlorophenylacetic acid	Union Carbide Agricultural Products Co., Inc. 300 Brookside Ave. Ambler, Pa. 19002
FL-3-22-82	Controlled release formulation of dichlobenil	Dr. Curt Thies, Washington Univ. St. Louis, Mo. 63130
Fluridone	1-methyl-3-phenyl-5-[3-(trifluoromethyl)-phenyl]-4(1H)-pyridinone	Lilly Research Laboratories Division of Eli Lilly and Co. P.O. Box 708, Greenfield, Ind. 46140
Fluridone monolithic fiber		Dr. Richard Dunn Southern Research Institute 2000 Ninth Ave. South Birmingham, Ala. 35205
Glyphosate	N-(phosphonomethyl)-glycine	Monsanto Co., Agricultural Products St. Louis, Mo. 63166
N-252 S-734	Confidential	Uniroyal Chemical 74 Amity Road Bethany, Conn. 06525
P-333	Confidential	ICI Americas Inc. P.O. Box 208 Goldsboro, N.C. 27530
Simazine	2-chloro-4,6,bis(ethyl-amino)-s-triazine	Ciba-Geigy Corp. Agricultural Division P.O. Box 11422 Greensboro, N.C. 27409
Terbutryn	2-(tert-butylamino)-4-ethylamino-6-(methylthio)-s-triazine(2-methylthio-4-ethylamino-6-tert-butylamino-s-triazine)	Ciba-Geigy Corp.
2,4-DDMA	Dimethylamine salt of 2,4-dichlorophenoxy acetic acid	Union Carbide
Poly (GMA) 2,4-D	2,4-dichlorophenoxyacetate/ glycerylmethacrylate	Dr. Frank Harris Wright State Univ. Dayton, Ohio 44231

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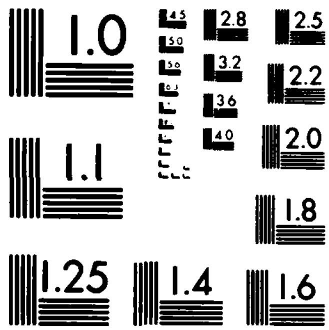

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MATERIALS AND METHODS

Evaluation of Controlled Release Formulations

Controlled release formulations. Two CR formulations of 2,4-D were provided by Dr. Frank Harris, Wright State University, Dayton, Ohio. The formulations are of a second generation of the clay pellets Poly (GMA) 2,4-D (12.5 percent a.e.*) and designed to give constant release rates of 3.0 mg (Lot 2) and 1.5 mg 2,4-D/g polymer/day (Lot 3).

The clay-filled alginate granules containing dichlobenil (7.1 percent a.i.**) were developed by the Southern Regional Research Institute (SRRC), U.S. Department of Agriculture, New Orleans, La. The release profile of the formulation was previously determined in static reconstituted water by the SRRC. The results indicated that the duration of action of the system was about 150 days. Release appeared to be first order with rates slowly declining with time. An average release of 0.45 mg dichlobenil/g granules/day was calculated for the system by averaging all rates over the 150-day activity of the formulation.

The monolithic fiber of fluridone (40 percent a.i.) was provided by Dr. Richard Dunn of the Southern Research Institute, Birmingham, Ala. The fiber formulation was expected to release all of its fluridone within approximately 1 month after treatment.

Determination of release rate in static water. Release rates of the CR herbicide formulations were determined first in static water tests under controlled laboratory conditions at 28° ± 2°C.

Treatments were made to 3.7 ℓ of water with amounts of CR formulations calculated to produce a given herbicide concentration based on estimated release rates specified by the cooperating formulators. Treatments were replicated four times.

Natural water from a dug pond on the Agricultural Research Center grounds was used. Water quality was monitored monthly (Table 2).

For interlaboratory comparisons, release rate data were also determined in reconstituted lake water, pH 8.0, containing 192 mg $NaHCO_3$, 120 mg $CaSO_4 \cdot 2H_2O$, 120 mg $MgSO_4$, and 8 KCl per litre of distilled water.

Water samples were taken from each container at various times throughout the experiment; herbicide concentrations were determined by high-pressure liquid chromatography (see Appendix A).

Determination of release rate in flowing natural water. Treatments of the CR formulations to maintain various herbicide concentrations were made to 19 ℓ of flowing natural water in glass, flow-through culture vessels, with and without plants and soil. Natural pond water was used and treatments were replicated four times.

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* a.e. = acid equivalent.
** a.i. = active ingredient.

Table 2
Water Quality Control Analysis

Date	Oxygen ppm	Conductivity μ mhos	pH	Alkalinity mg/ℓ$CaCO_3$	Hardness mg/ℓ$CaCO_3$	Air Temp °C	Water Temp °C
Mar 82	2.80	319	7.61	152.0	182.0	25.0	25.0
Jun 82	4.10	348	7.74	150.0	172.0	32.0	30.0
Sep 82	2.56	340	7.39	153.0	182.0	30.0	28.0
Dec 82	3.0	327	7.53	165.0	179.0	17.0	20.0

Date	Phosphate mg/ℓ	Nitrate mg/ℓ	Ammonia mg/ℓ	K mg/ℓ	Solids Total mg/ℓ	Solids Suspended mg/ℓ
Mar 82	BDL	1.21	0.29	—	250	4.0
Jun 82	BDL	1.90	0.13	0.56	252	4.0
Sep 82	BDL	0.19	0.42		292	3.0
Dec 82	BDL	BDL	0.43		340	20.0

Regulated flowing water provided by a multichannel tubing pump (Eldex Laboratories Inc., 3551 Heaven Ave., Menlo Park, Calif.) was delivered to the bottom of individual culture vessels at a rate to provide one volume change in 24 hr. Water flow was checked at least once a week and adjusted when necessary.

Wastewater flowed out through side arms near the top of the vessels and was carried outside. Residual herbicide in solution was removed by passage of the wastewater through three series-connected containers filled with activated charcoal.

Fifty-millilitre water samples were taken from each vessel at various times throughout the experiment. The samples were concentrated on SEP PAK® C_{18} cartridges and analyzed for herbicide residues (see Appendix A).

Evaluation of efficacy against watermilfoil and hydrilla in flowing water. Mature plants of watermilfoil were obtained from Lake Seminole, Georgia. The plants were maintained as a stock culture in an outdoor aquarium until use. Mature plants and tubers of hydrilla were collected locally.

The two formulations of Poly (GMA) 2,4-D were evaluated for control of watermilfoil in the laboratory. Apical stem sections 15 cm long were planted in standard soil mix (70 percent sand and 30 percent organic peat) in 250-ml glass beakers. Five beakers, each containing three plant sections, were placed in the culture vessels and allowed to establish for 4 weeks before chemical treatment was applied. Culture vessels were subjected to 14-hr days of 150 μ E/m^2/sec from a combination of fluorescent and incandescent lamps. Temperature was maintained at 28° ± 2°C.

Treatments were applied to vessels containing watermilfoil and to vessels without plants in order to determine the effect of plants and soil on herbicide concentrations. Culture vessels with plants to which treatments were not applied served as plant controls.

Response of watermilfoil plants to chemical treatments under flowing water conditions was evaluated closely throughout the experiment. The plants were harvested 10 weeks after treatment and evaluated for percent survival. Stem lengths and plant weights were measured.

The CR formulations of dichlobenil and fluridone were evaluated for control of hydrilla regrowth from rootstocks and from germinating tubers. Hydrilla tubers were pregerminated in pond water in the laboratory. The new shoots emerging from tubers were selected for uniformity (3 cm long) and planted in 250-ml beakers. Three beakers each containing three germinating tubers were placed in the culture vessels, and regrowth was observed with or without CR herbicide treatments.

For studies of regrowth from rootstocks, apical stem sections of hydrilla were planted in 250-ml beakers and allowed to establish for 3 to 4 months in an outdoor pool. The plants were then clipped to 3 cm above the hydrosoil and the beakers transferred into the culture vessels 1 week before chemical treatment was applied.

Outdoor evaluation of CR 2,4-D. The outdoor evaluation of Poly (GMA) 2,4-D against watermilfoil was conducted from April through August 1982. A system of 24 concrete, flow-through aquaria was used. The dimensions of the aquaria were 77 cm wide × 219 cm long (1.7×10^{-4} ha) with depth varying from 50 to 56 cm. The normal volume of these containers after adding soil was 850 to 950 *l*. A shelter with clear fiberglass roofing panels was constructed over the system to prevent rainwater from entering the aquaria. The aquaria were filled with natural pond water. Uniform low water pressure was maintained by constant overflow in a standpipe, and flow to individual aquaria was regulated by small pet cock valves to provide one volume change every 24 hr.

Watermilfoil plants were established in 30- by 30-cm-square aluminum trays, 15 cm deep. Twelve trays were placed in each culture aquaria and allowed to grow for 6 months before chemical treatment was applied.

Evaluation of Conventional Formulations

Laboratory evaluation techniques for submersed aquatic plants. Apical sections of submersed plants were planted in a standard soil mix in small plastic pots and placed in 3.8- or 19-*l* jars filled with pond water. Plants were then allowed to become established for approximately 1 week under controlled conditions of temperature (25°C) and light (25 to 40 μ E/m²/sec, from Gro-lux fluorescent tubes, 14-hr photoperiods). The plants were treated by injecting treatment solutions into the water with a hypodermic syringe. The treatments were then evaluated biweekly for phytotoxicity for a period of 8 to 14 weeks, depending on the herbicide.

Laboratory evaluations of chemicals for growth inhibition of hydrilla propagules. Vegetative propagules (tubers) of hydrilla were planted in four 5-cm pots (five tubers per pot). These pots were placed in a 3.8-*l* jar filled with water. Chemical treatments were applied at the time of planting. Effects on germination were recorded along with phytotoxic response of sprouted plants. These tests were

conducted in a growth lab under conditions of controlled light and temperature as described above.

Herbicides were also bioassayed for efficacy against new growth emerging from germinated tubers planted in soil. In these tests, tubers were pregerminated in pond water in the laboratory. The new shoots emerging from tubers were selected for uniformity (3 cm long) and planted in 5-cm pots, three tubers per pot. Four pots were placed in a 3.8-ℓ jar filled with pond water, and chemical treatment was applied. The plants were harvested 10 weeks after treatment, and percent of surviving plants, percent injury, shoot length, and shoot and root dry weights were determined.

Greenhouse evaluation techniques for emergent and floating aquatic plants. Plants to be treated were grown in polyethylene-lined, 12-ℓ capacity plastic containers, and allowed to become established in a screenhouse for a period of approximately 2 to 4 weeks prior to treatment. Each replicated treatment was applied by placing the container in a 929-cm^2 enclosure with an open top. The plants were then uniformly sprayed with a small atomizer. The total spray volume was equivalent to 935 ℓ/ha. Following application of the chemicals, the plants were moved to the screenhouse where treatments were periodically evaluated for phytotoxicity.

Evaluation techniques in outside aquaria. Evaluations were conducted in aquaria of two sizes and types. One type consisted of circular, vinyl-lined containers manufactured for use as swimming or wading pools. The dimensions were 3.05 m in diameter (7.3×10^{-4} ha) with a maximum depth of 60 cm. The maximum volume was 4400 ℓ. The pools were filled to a 53-cm depth, which resulted in a volume of 3870 ℓ.

The second type of aquarium consisted of rectangular-shaped concrete boxes. The interior of each box was covered with two coats of white epoxy paint. The dimensions were 77 cm wide by 219 cm long (1.7×10^{-4} ha) with depth varying from 56 to 65 cm. The maximum capacity of these containers ranged from 945 to 1095 ℓ and the normal volume after adding soil was 850 to 950 ℓ.

When these aquaria were used to evaluate herbicide efficacy on submersed plants, apical cuttings of individual species were established by planting 15 cuttings 15 cm long in 30- by 30- by 15-cm aluminum trays. The trays were filled with standard soil mix (70 percent sand and 30 percent organic peat) supplemented with 5 percent (v/v) manure. Twelve trays were placed in each of the aquaria. The plants were subjected to a continuous water flow until treatments were applied. For evaluation of herbicide efficacy on floating plant species, field-collected plants were established in the aquaria and allowed to completely cover the water surface before treatment.

All chemical treatment rates were replicated a minimum of three times and were applied on an area (kilograms per hectare) or volume (milligrams per litre) basis. Phytotoxicity ratings, determined at various times after treatment, were made on a scale of 0 to 100 percent injury: 0 percent being no injury, and 100 percent being complete elimination of live plant tissue.

Field Evaluations

Several finger canals uniformly infested with waterhyacinth located in the Fort Lauderdale, Fla., area, north of State Road (SR) 84 and just west of SR 27, were selected in September 1982 to evaluate the effects of glyphosate (Scout®), DPX-5648, and AC-925 on waterhyacinth. The canals were 18 m wide and had an average depth of about 3 m at high tide. A plot about 30 to 35 m long was treated in each of the canals.

The plot in Canal 1 was treated with 10 g a.i./ha DPX-5648, Canal 2 with 20 g a.i./ha DPX-5648, Canal 3 with 3.36 kg a.e./ha glyphosate, and Canal 4 with 0.28 kg a.i./ha AC-925. These rates were chosen based on earlier results of evaluations under greenhouse conditions and/or in outdoor aquaria. The surfactant X-77 was used at 0.25 percent concentration in the spray solution.

The herbicides were treated from an airboat which contained a 400-*ℓ* fiberglass tank mix system with mechanical agitation calibrated to deliver 1870 *ℓ*/ha through a Bean® rotating handle spray gun equipped with a No. 11 orifice disc.

Phytotoxicity ratings, determined at various times after treatment, were made on a scale of 0 to 100 percent injury: 0 percent being no injury, and 100 percent being complete elimination of live plant tissue.

The persistence of DPX-5648 in the aquatic environment after chemical treatment of waterhyacinth was investigated in a cooperative study with DuPont Company.

The study was conducted in August 1982 on a 0.07-ha dug pond on the Fort Lauderdale Agricultural Research and Education Center (AREC) grounds. The pond had a mean depth of 1.2 m and was about 80 percent covered with waterhyacinth at the time of treatment. The waterhyacinth appeared free of any disease, but did exhibit evidence of moderate feeding by waterhyacinth weevils, *Neochetina* spp.

The herbicide DPX-5648 (20 g a.i./ha) was applied from the bank with a rotating handle spray gun calibrated to deliver 1400 *ℓ*/ha. The surfactant X-77 at 0.25 percent was used.

Water and hydrosoil samples were taken from two different sites in the pond before treatment and at various times after treatment. Water samples were collected at three different depths from each site in 1-*ℓ* polyethylene bottles fitted into a specially designed housing that allowed the cap to be removed and replaced at any desired depth. A liner-type core sampler fitted to a 3.4-m galvanized pipe handle was used to collect hydrosoil samples. Each core was 20 cm deep and 5 cm in diameter.

Bluegills (*Lepomis macrochirus*) and catfishes (*Ictalurus punctatus*) were also collected at various times before and after treatment for residue analyses.

The water, hydrosoil, and fish samples were shipped to E. I. DuPont de Nemours and Company, Wilmington, Del., to be analyzed for chemical residues.

RESULTS AND DISCUSSION

Evaluation of Controlled Release Formulations

Release of 2,4-D from clay pellets of poly(GMA) 2,4-D static water. Figure 1 illustrates the cumulative release of 2,4-D from the two formulations of Poly(GMA) 2,4-D in static reconstituted water. The increasing levels of herbicide in the water with time indicated that release from the formulations had occurred. Release rates in both formulations appeared fairly constant, except that the rate appeared to slow slightly in Lot 2 after 68 days, when approximately 70 percent of the chemical had been released. The rates of release in reconstituted water were estimated to be 5.4 mg and 0.9 mg 2,4-D per gram polymer per day for Lot 2 and Lot 3, respectively. Regression equations of the release rate data from Day 0 to Day 112 were $Y=3.6 + 5.4X$, $R=0.98$ for Lot 2, and $Y=4.5 + 0.9X$, $R=0.95$ for Lot 3.

The results of cumulative 2,4-D release in natural pond water are presented in Table 3. Considerable variability among the replicated samples was observed. Between Day 14 and Day 20, levels of 2,4-D in treatments with both formulations actually dropped as compared to levels from previous measurements, suggesting that some degradation of the released chemical had occurred.

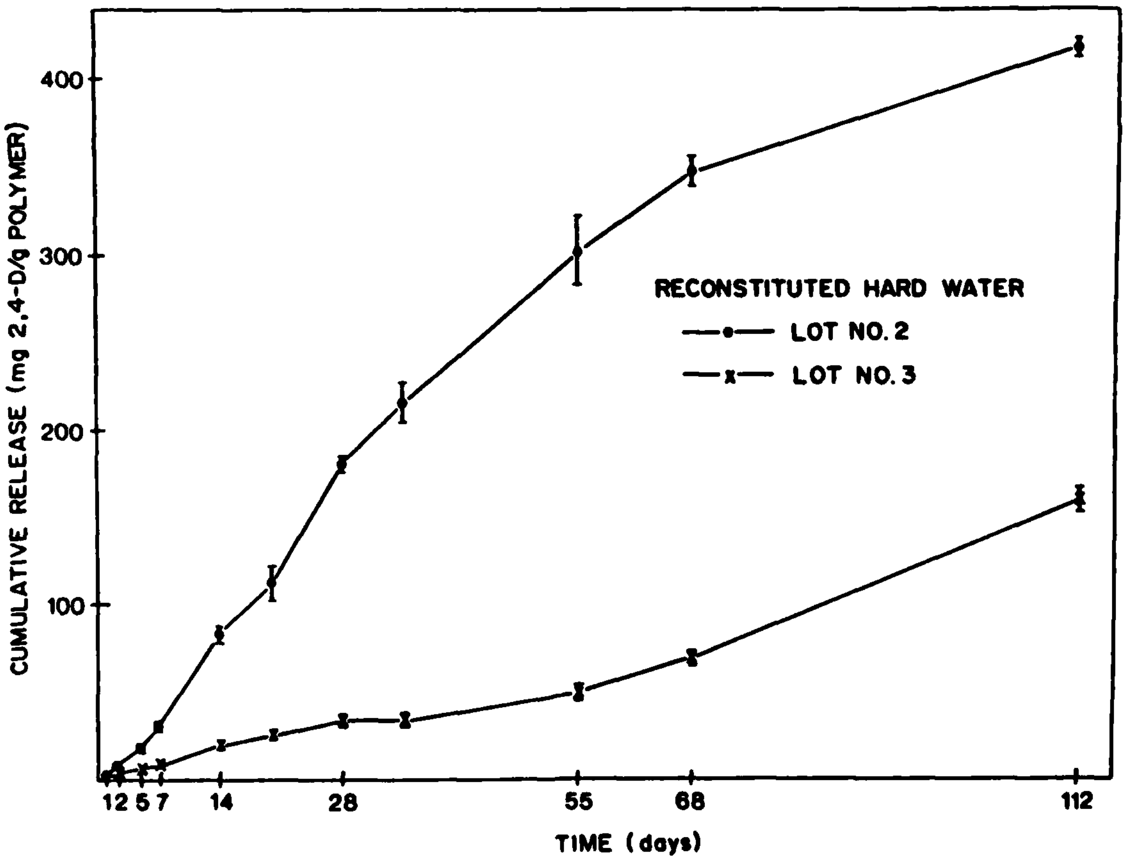

Figure 1. Release of 2,4-D from clay pellets of Poly(GMA) 2,4-D in static reconstituted water. Each point is the mean of four replicates ± S.E.

Table 3
Release of 2,4-D from Clay Pellets Poly (GMA) 2,4-D in Static Natural Pond Water

	Days Posttreatment										
*Treatment**	*1*	*2*	*5*	*7*	*14*	*20*	*28*	*35*	*55*	*68*	*112*
Lot 2											
A	2.2	3.7	6.0	8.6	2.5**	2.2**	12.8	33.6	74.0	174.7	185.3
B	—	4.3	7.2	10.5	12.4	16.8	50.5	84.2	118.8	195.1	252.7
C	1.6	3.6	6.9	11.5	6.3**	1.4**	4.9	19.8	80.1	199.6	302.1
D	2.4	4.6	6.5	8.1	6.1**	2.4**	12.9	25.7	86.1	175.1	278.4
Average	2.1	4.1	6.7	9.7	6.8	5.7	20.3	40.8	89.8	186.1	254.6
Lot 3											
A	1.8	3.3	4.2	6.5	2.0**	2.5	0.6**	BDL	BDL	13.9	34.2
B	—	2.4	3.7	7.4	5.8**	0.8**	1.8	BDL	BDL	11.9	95.0
C	1.6	3.3	4.5	7.2	3.4**	3.3**	1.2**	BDL	BDL	13.9	131.1
D	—	4.0	4.9	7.4	0 **	2.2**	1.2**	BDL	BDL	11.9	142.5
Average	1.7	3.3	4.3	7.1	2.4	2.2	1.2	BDL	BDL	12.9	100.7

NOTE: Units in mg/g polymer.

* Treatments of clay pellets Poly(GMA) 2,4-D made to pond water with amounts calculated to produce a concentration of 0.10 mg/ℓ herbicide every 24 hr, based on estimated release rates of 3.0 and 1.5 mg/g polymer for Lot 2 and Lot 3, respectively.

** A decline of 2,4-D levels as compared to those from previous measurements indicates partial disappearance of the released chemical, probably by degradation.

A study of the accountability of 2,4-D in treatments with reconstituted water and natural pond water was conducted at the conclusion of the experiment on Day 112. The treatments were stirred vigorously to obtain a homogeneous mixture, and two 100-ml samples were taken immediately after stirring. Suspended particulate matter containing 2,4-D was collected by filtering the sample through a combination of Reeve-Angel® glass microfiber and Gelman Metrigard® filter (0.2 μ pore size). The portion of 2,4-D that had been hydrolyzed and adsorbed onto clay particles was recovered by first eluting with 10 ml ethanol (95 percent) and finally desorbing with another 10 ml ethanol (95 percent). The remaining 2,4-D polymer collected on the filter was then dissolved in acetone and subjected to complete hydrolysis at pH 2. However, no 2,4-D acid was recovered from the final acid hydrolysis step, suggesting that all 2,4-D had been released from the polymer in both treatments in reconstituted water and in natural water. The results of analyses for 2,4-D in the ethanol fractions and the aqueous filtrate are presented in Table 4.

It appears that all of the available 2,4-D was recovered from treatments in reconstituted water. About 76 percent was measured in the aqueous filtrate, 14 percent in the ethanol eluent, and 12 percent in the ethanol desorption mixture. On the other hand, total 2,4-D recovered from treatments made to natural water averaged only 73 percent. About 48 percent was recovered in the aqueous filtrate, 25 percent recovered from the ethanol fractions, and 27 percent was not accounted for. Higher microbial activity and algal growth were observed in treatments with natural pond water. These factors may have been partly responsible for the loss of the released 2,4-D in natural water.

Table 4
Accountability of 2,4-D Released in Static Reconstituted and Natural Water

Total 2,4-D Applied mg	2,4-D Recovered 5 Months After Treatment, mg*				
	Aqueous Filtrate	EtOH Eluent	EtOH Desorption	Total Recovery	Percent Recovery
Reconstituted Water					
(187)	142.9 ±7.6	26.5 ±0.4	22.7 ±3.2	192.0 ±4.1	102
Natural Pond Water					
(187)	89.0 ±6.0	24.4 ±3.2	22.8 ±0.5	136.2 ±8.8	73

* Means of three replicates ± standard error.

Release of 2,4-D from clay pellets of Poly (GMA) 2,4-D in flowing natural water and efficacy against watermilfoil. Treatments of the two clay pellets Poly (GMA) 2,4-D were made to 19 ℓ of flowing water in glass, flow-through culture vessels with and without Eurasian watermilfoil. Rates of treatment were calculated to maintain 0.05 and 0.10 mg/ℓ 2,4-D concentrations in the culture vessels, based on the estimated release rates specified by the cooperating formulator (3.0 mg and 1.5 mg 2,4-D/g polymer/day for Lot 2 and Lot 3, respectively).

Results of measurements of 2,4-D concentrations in the flowing water at various sampling times after treatment are presented in Table 5. Based on these concentrations, release rates of 2,4-D from the formulations were calculated. During the first week after treatment, average release rates for Lot 2 were 5.6, 3.9, and 3.4 mg 2,4-D/g polymer/day on Days 1, 3, and 7, respectively. Corresponding values for Lot 3 were 4.0, 1.9, and 0.4 mg 2,4-D/g polymer/day.

Treatments with both Lot 2 and Lot 3 to maintain 0.10 mg/ℓ 2,4-D were applied to vessels containing watermilfoil and to vessels without plants in order to

Table 5
Release of 2,4-D from Clay Pellets Poly (GMA) 2,4-D Lot 2 and
Lot 3 in Flowing Natural Water Under Controlled Laboratory Conditions

2,4-D Treatment	Concentration of 2,4-D (mg/ℓ) at Days Posttreatment*							
	1	3	7	14**	21	35	49	63
0.05 mg/ℓ, Lot 2 with plants	0.08 ±0.02	0.07 ±0.02	0.08 ±0.01	—	0.07 ±0.05	BDL	BDL	0
0.10 mg/ℓ, Lot 2 with plants	0.19 ±0.04	0.16 ±0.03	0.14 ±0.02	0.55 ±0.07	0.29 ±0.13	BDL	0	0
0.10 mg/ℓ, Lot 2 no plants	0.21 ±0.08	0.09 ±0.03	0.04 ±0.02	0.94 ±0.08	0.35 ±0.12	0.08 ±0.03	0.09 ±0.04	0.11 ±0.02
0.10 mg/ℓ, Lot 3 with plants	0.26 ±0.08	0.15 ±0.04	0.03 ±0.01	0.16 ±0.07	0.02 ±0.02	BDL	BDL	0
0.10 mg/ℓ, Lot 3 no plants	0.26 ±0.08	0.10 ±0.01	0.02 ±0.01	0.23 ±0.11	0.17 ±0.07	0.11 ±0.08	0.13 ±0.04	0.10 ±0.03

* Means of four replicates ± standard error.

** Power failure resulting in stop of flow.

determine the effects of plants and soil on herbicide concentrations. In the absence of plants and soil, concentrations of 2,4-D appeared to be maintained around the expected level (0.10 mg/l 2,4-D) until the end of the 63-day experiment (Table 5). In all treatments with watermilfoil, however, 2,4-D concentrations decreased rapidly and disappeared from the flowing water after 35 days posttreatment. Similar losses of 2,4-D were previously reported (Van and Steward 1981), and were probably due to the various components in the experimental system acting as sinks in taking up the released 2,4-D.

On 30 April and 01 May 1982, water flow through the experimental vessels was stopped because of power failure, resulting in exceedingly high levels of 2,4-D in the culture vessels, as reflected in results of residue analyses on Day 14.

These high residue levels in the flowing water were probably responsible for the severe plant injuries observed in all treatments after 14 days (Table 6). However, regrowth began as early as 42 days after treatment, and appeared to be much more vigorous in the treatment with Lot 3. All plants were harvested 10 weeks after treatment, and percent of surviving plants, stem length, and plant dry weights were measured (Table 7). The dry weights as well as growth in stem length were significantly inhibited in all treatments with the 2,4-D polymers.

Table 6
Phytotoxicity of 2,4-D Released from Clay Pellets Poly (GMA) 2,4-D Toward Watermilfoil in Flowing Water Under Controlled Laboratory Conditions

2,4-D Treatment	*Percent Injury at Days Posttreatment**					
	7	*14*	*28*	*42*	*56*	*70*
Control	0	0	5	8	11	15
0.05 mg/l, Lot 2	20	62	81	76**	55	38
0.10 mg/l, Lot 2	26	68	88	91**	74	78
0.10 mg/l, Lot 3	26	70	78	78**	58	30

* Average of four replicated jars.

** Reduction in injury rating indicates plant recovery and regrowth.

Table 7
Effect of 2,4-D Released from Clay Pellets Poly (GMA) 2,4-D on Watermilfoil after 10 Weeks in Flowing Water*

2,4-D Treatment	*Percent Surviving Plants*	*Stem Length cm*	*Shoot Dry Weight g*	*Root Dry Weight g*
Control	95^{a}	61.0^{a}	1.10^{a}	0.16^{a}
0.05 mg/l, Lot 2	20^{b}	11.5^{bc}	0.06^{bc}	0.03^{b}
0.10 mg/l, Lot 2	12^{b}	6.0^{c}	0.02^{c}	0.02^{b}
0.10 mg/l, Lot 3	33^{b}	17.4^{b}	0.14^{b}	0.03^{b}

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan Test. Each value is the mean of four replicates.

Outdoor evaluation of Poly(GMA) 2,4-D. Treatments of the two clay pellets Poly(GMA) 2,4-D were applied to maintain 0.05, 0.10, and 0.20 mg/ℓ 2,4-D in outdoor aquaria previously established with watermilfoil. Results of 2,4-D analyses in the flowing water at various times during the experiment are presented in Table 8. After 7 days, the measured concentrations of 2,4-D in the flowing water were close to the expected levels. The 2,4-D concentrations then declined gradually in all treatments, and disappeared from the flowing water during the last several weeks of the experiment.

Because of several power failures resulting in chemical buildups in the aquaria around Day 3 posttreatment (Table 8), severe plant damage occurred in all treatments as observed in the 4-week evaluation (Table 9). Plant injury ratings 20

Table 8
Release of 2,4-D from Clay Pellets Poly (GMA) 2,4-D in Flowing Natural Water in Outdoor Aquaria

Treatment No.	2,4-D Treatment	Weight Pellets Applied g*	Concentration of 2,4-D (mg/ℓ) at Days Posttreatment** 1	3†	7	14	21	35	49	83	120
I	0.05 mg/ℓ, Lot 2	60.2	0.06 ±0.03	0.26 ±0.06	0.06 ±0.03	0.12 ±0.03	0.01 ±0.01	0.01 ±0.01	0.01 ±0.01	0	0
II	0.10 mg/ℓ, Lot 2	120.4	0.09 ±0.04	0.63 ±0.17	0.11 ±0.06	0.21 ±0.07	0.03 ±0.01	0.01 ±0.01	0.02 ±0.02	0	0
III	0.20 mg/ℓ, Lot 2	240.8	0.21 ±0.06	0.64 ±0.18	0.20 ±0.01	0.23 ±0.08	0.01 ±0.01	0.04 ±0.02	0.02 ±0.02	0	0
IV	0.05 mg/ℓ, Lot 3	120.4	0.07 ±0.00	0.09 ±0.02	0.02 ±0.02	0.03 ±0.02	0.02 ±0.01	0.01 ±0.02	0.01 ±0.01	0	0
V	0.10 mg/ℓ, Lot 3	240.8	0.11 ±0.02	0.16 ±0.03	0.08 ±0.03	0.04 ±0.03	0.06 ±0.04	0.01 ±0.01	0.03 ±0.02	0	0
VI	0.20 mg/ℓ, Lot 3	481.6	0.26 ±0.03	0.39 ±0.06	0.11 ±0.04	0.15 ±0.06	0.04 ±0.06	0.04 ±0.03	0.06 ±0.04	0.02 ±0.02	0

* Total treatment, assuming complete release, equals to: 8.2, 16.3, and 32.7 mg/ℓ 2,4-D with Lot 2 in treatments I, II, III; and 16.3, 32.7, and 65.3 mg/ℓ 2,4-D with Lot 3 in Treatments IV, V, and VI, respectively.

** Means of three replicates ± standard error.

† Power failure resulting in stop of flow.

Table 9
Phytotoxicity of 2,4-D Release from Clay Pellets Poly (GMA) 2,4-D on Watermilfoil in Flowing Water in Outdoor Aquaria

2,4-D Treatment	Percent Injury at Weeks Posttreatment* 1	2	4	6	8	10	12	16	20
Control	0	2	0	2	2	2	3	5	7
0.05 mg/ℓ, Lot 2	22	43	75	88	87	83**	80	72	60
0.10 mg/ℓ, Lot 2	23	50	80	92	93	93	93	90	98
0.20 mg/ℓ, Lot 2	13	37	82	92	93	88	88	85**	82
0.05 mg/ℓ, Lot 3	20	27	70	63**	63	43	40	40	37
0.10 mg/ℓ, Lot 3	15	35	65	60**	57	48	48	45	43
0.20 mg/ℓ, Lot 3	23	50	85	90	90	90	90	88	93

* Mean values of three replicates.

** Reduction in injury rating indicates recovery and regrowth.

weeks after treatment, however, reflected the difference in regrowth in the various treatments. Treatments of Lot 2 to maintain 0.10 mg/l 2,4-D in the flowing water appeared adequate for control of regrowth in these tests.

Lot 3 at the same treatment rates was much less effective, judging from the amounts of regrowth and plant dry weights at the end of the 20-week experiment (Table 10). Complete plant control was obtained, however, with treatment of Lot 3 calculated to maintain 0.02 mg/l 2,4-D in the flowing water.

Release of dichlobenil from clay-filled dichlobenil-alginate granules in flowing water and efficacy against hydrilla regrowth. In these studies, the clay-filled alginate granules containing dichlobenil were evaluated for reliability of maintaining low levels of dichlobenil in flowing water to control hydrilla regrowth from germinating tubers and from rootstocks. Based on the average release rate of 0.45 mg dichlobenil/g granules/day previously observed in static water, treatments were made to maintain various levels of dichlobenil in culture vessels with or without hydrilla. Residue levels in the flowing water and efficacy of the formulation in controlling plant regrowth were determined.

Table 11 shows the actual dichlobenil concentrations in the flowing water at various times during the experiment. A gradual decline of the herbicide concentrations with time was observed in all treatments, with or without plants and soil—suggesting that release from the dichlobenil-alginate system was first-order, as it was previously shown in static water tests. No significant difference in herbicide concentrations was observed between treatments with and without plants and soil.

Regrowth from both germinating tubers and rootstocks (Table 12) was completely inhibited in treatments where dichlobenil concentrations in the flowing water were maintained at levels above 0.04 mg/l. Regrowth was observed only at the lowest treatment rate where dichlobenil levels dropped to 0.03 and 0.01 mg/l after 4 and 6 weeks posttreatment, respectively. Both shoot growth and root growth were affected by the dichlobenil treatments.

Release of dichlobenil from various CR formulations in static water. Various CR formulations containing dichlobenil were evaluated in the laboratory in static reconstituted water and natural pond water. Treatments of the formulations were made to 1-l Erlenmeyer flasks with amounts calculated to provide a concentration of 10 mg/l dichlobenil in the flask, assuming complete chemical release. The flasks were tightly capped to minimize loss of herbicide through volatility.

Table 13 presents results of evaluation of the dichlobenil formulation FL-3-22-82 (1 percent a.i.). The commercial formulations Casoron-G (6.75 percent a.i.) and Casaron-GSR (20 percent a.i.) were included for reference.

Casoron-G was found to release about 80 percent of its dichlobenil 1 week after treatment, and 100 percent within 2 weeks. On the other hand, complete release of dichlobenil from Casoron-GSR was obtained in about 4 weeks.

Release of dichlobenil from the formulation FL-3-22-82 also was completed in about 4 weeks after treatment, and, therefore, represents no significant

Table 10

Effect of 2,4-D Released from Clay Pellets Poly (GMA) 2,4-D on Watermilfoil after 20 Weeks in Flowing Water in Outdoor Aquaria*

2,4-D Treatment	Lot 2 Shoot Dry Weight g	Lot 2 Root Dry Weight g	Lot 3 Shoot Dry Weight g	Lot 3 Root Dry Weight g
Control	227.3^{a}	37.9^{a}	227.3^{a}	37.9^{a}
0.05 mg/l	47.4^{b}	11.5^{b}	100.6^{b}	17.9^{ab}
0.10 mg/l	0.1^{c}	12.0^{b}	136.5^{b}	16.7^{ab}
0.20 mg/l	9.3^{c}	10.7^{b}	0.1^{c}	3.3^{b}

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan Test. Each value is the mean of three replicates.

Table 11

Measured Release of Dichlobenil from Clay-Filled Alginate Granules in Flowing Water

Treatment No.	Dichlobenil Treatment*	Weight Granules g	Dichlobenil (mg/l) at Days Posttreatment** 7	21	28	42
I	0.01 mg/l, with plants	0.3973	0.07 ±0.01	0.04 ±0.01	0.03 ±0.01	0.01 ±0.00
II	0.025 mg/l, with plants	0.9911	0.16 ±0.01	0.12 ±0.01	0.08 ±0.01	0.04 ±0.02
III	0.05 mg/l, with plants	1.9837	0.32 ±0.05	0.22 ±0.02	0.24 ±0.08	0.06 ±0.01
IV	0.10 mg/l, with plants	3.9582	0.50 ±0.10	0.41 ±0.01	0.21 ±0.02	0.11 ±0.01
V	0.10 mg/l, no plants	3.9608	0.39 ±0.11	0.34 ±0.02	0.23 ±0.03	0.13 ±0.08

* Total treatment, assuming complete chemical release, equals to 1.6, 4.0, 7.9, 15.8, and 14.9 mg/l dichlobenil in treatments I, II, III, IV, and V, respectively.

** Means of four replicates ± standard error.

Table 12

Effect of Dichlobenil-Alginate Granules on Hydrilla Regrowth from Germinating Tubers and from Rootstocks after 6 weeks in Flowing Water*

Dichlobenil Treatment	Regrowth from Tubers: Shoot Length cm	Shoot Weight g	Root Weight g	Root/Shoot Ratio	Regrowth from Rootstocks: Shoot Length cm	Shoot Weight g	Root Weight g	Root/Shoot Ratio
Control	50^{a}	1.44^{a}	0.188^{a}	0.13^{a}	38^{a}	0.44^{a}	0.087^{a}	0.20
0.010 mg/l	18^{b}	0.20^{b}	0.024^{b}	0.12^{a}	17^{b}	0.18^{b}	0.036^{b}	0.20
0.025 mg/l	5^{c}	0.06^{c}	0.004^{c}	0.07^{b}	5^{c}	0.16^{b}	0.024^{c}	0.14
0.050 mg/l	4^{c}	0.03^{c}	0.003^{c}	0.08^{b}	4^{c}	0.13^{b}	0.030^{bc}	0.23
0.100 mg/l	5^{c}	0.04^{c}	0.002^{c}	0.06^{b}	6^{c}	0.18^{b}	0.034^{bc}	0.19

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicates.

Table 13
Release of Dichlobenil from Various Formulations in Static Water

Sample*	Weight Formulation g/l	Weight Dichlobenil mg/l	Dichlobenil (mg) Released at Days Posttreatment 1	3	7	14	28
			Casoron-G (6.75% a.i.)				
RCW 1	0.1487	10.04	2.06	6.82	7.89	10.83	12.23
2	0.1487	10.04	4.13	7.54	8.05	9.35	11.12
3	0.1510	10.19	2.08	7.39	7.71	9.38	11.31
4	0.1486	10.03	2.11	5.44	6.24	8.91	10.47
Average		10.07	2.60	6.80	7.47	9.62	11.28
PW 5	0.1552	10.48	2.24	8.49	8.38	10.61	12.82
6	0.1514	10.22	3.19	7.75	8.32	10.43	10.64
7	0.1520	10.26	2.94	8.48	9.34	10.85	12.02
8	0.1502	10.14	2.44	7.76	8.13	10.47	11.15
Average		10.28	2.70	8.12	8.54	10.59	11.66
			Casoron-GSR (20% a.i.)				
RCW 9	0.0603	12.06	1.59	4.09	5.15	7.23	8.71
10	0.0555	11.10	1.15	2.47	4.93	6.69	9.11
11	0.0592	11.84	1.34	3.46	5.15	6.63	8.93
12	0.0624	12.48	1.60	3.58	5.77	8.22	10.90
Average		11.87	1.42	3.40	5.25	7.19	9.41
PW 13	0.0561	11.22	1.51	2.67	4.97	7.93	10.64
14	0.0589	11.78	1.62	3.33	4.18	6.85	9.59
15	0.0601	12.02	1.82	3.35	5.94	6.91	9.78
16	0.0567	11.34	1.88	3.74	3.82	7.10	9.63
Average		11.59	1.71	3.27	4.73	7.20	9.91
			FL-3-22-82 (1% a.i.)				
RCW 17	1.0116	10.12	1.22	2.74	5.63	7.75	9.67
18	1.0043	10.04	1.01	3.24	4.07	7.66	8.72
19	1.0020	10.02	2.12	3.32	4.49	7.09	7.75
20	1.0039	10.04	1.97	3.26	4.79	8.93	13.04
Average		10.05	1.58	2.89	4.75	7.81	9.79
PW 21	1.0050	10.05	1.41	2.17	3.86	7.12	8.84
22	1.0099	10.10	1.34	2.02	3.58	7.80	10.37
23	1.0007	10.01	1.74	2.19	4.16	9.84	12.49
24	1.0074	10.07	2.79	3.30	4.28	8.16	10.40
Average		10.06	1.82	2.42	3.97	8.23	10.53

* RCW = reconstituted water; PW = pond water.

improvement over the reference commercial formulation Casoron-GSR.

Much slower release rates were obtained with two CR formulations D1 (10 percent a.i.) and D2 (10 percent a.i.) The release appeared to be first-order (Figure 2), with about 54 percent and 36 percent dichlobenil released over a period of 3 months for D1 and D2, respectively.

The reference formulation Casoron-GSR was found again to release all of its dichlobenil in about 30 days (Figure 2).

Monolithic fiber containing fluridone in static water. Figure 3 illustrates the cumulative release of the monolithic fiber containing fluridone in reconstituted water and natural pond water.

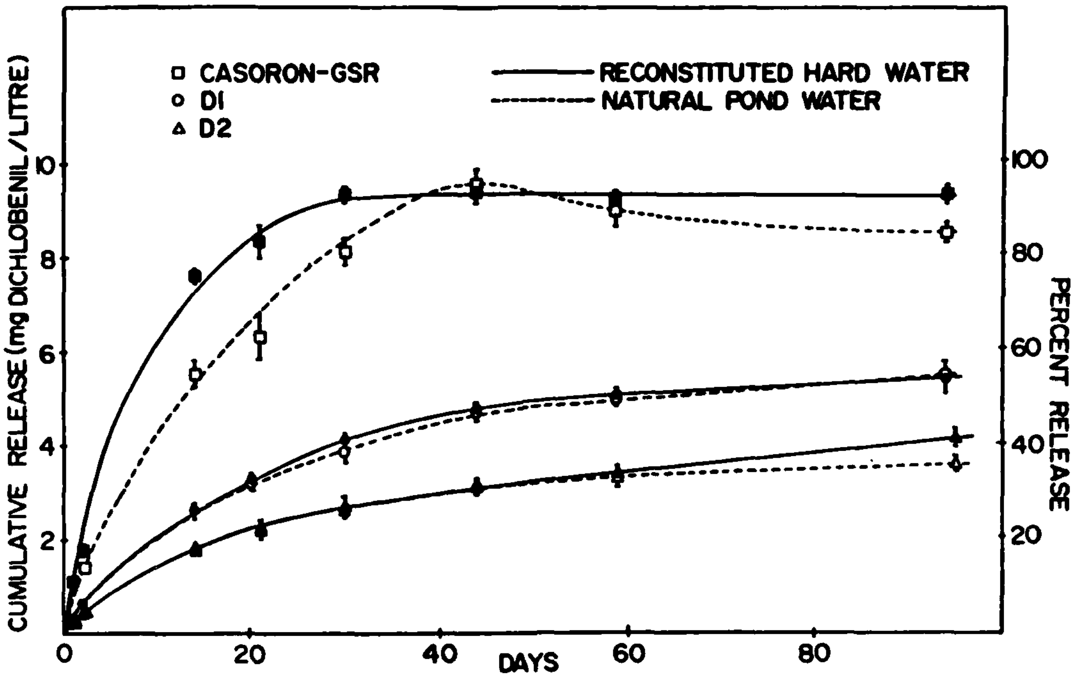

Figure 2. Release of dichlobenil from various CR formulations in static reconstituted water and natural pond water. Each point is the mean of four replicates ± S.E.

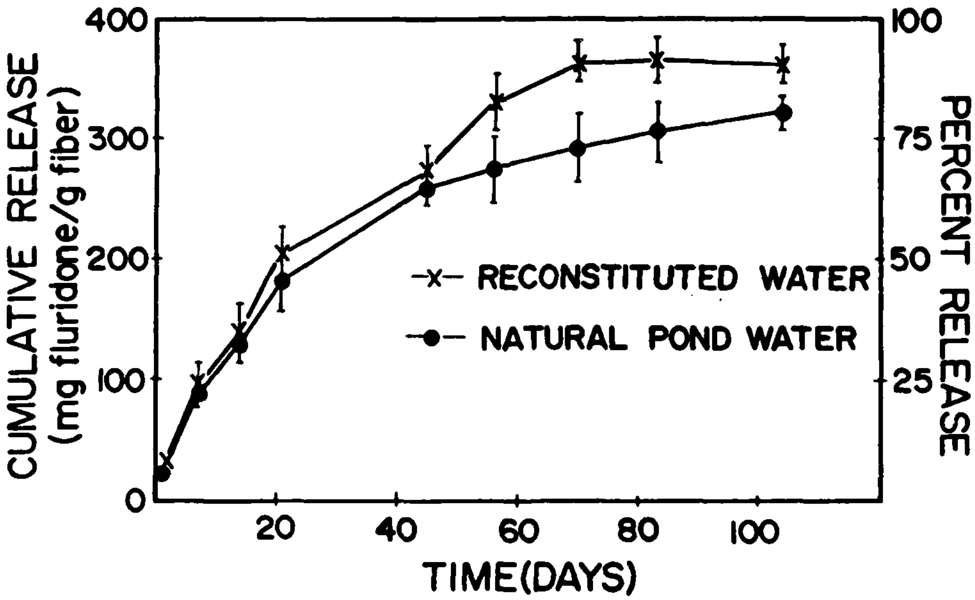

Figure 3. Release of fluridone from monolithic fiber formulation in static reconstituted water and in natural pond water. Each point is the mean of four replicates ± S.E.

In reconstituted water, release rates appeared fairly constant during the first 3 weeks after treatment ($Y = 18.2 + 9.0X$, $R = 0.97$), but slowed down significantly during the next 7 weeks ($Y = 134.8 + 3.3X$, $R = 0.95$). About 60 percent of total fluridone in the formulation was released by 1 month after treatment, and another 30 percent released during the second month. No further release was observed after 70 days posttreatment when approximately 90 percent of total fluridone had been released.

Release rates appeared somewhat slower in natural pond water than in reconstituted water. However, the cumulative levels of fluridone were not significantly different until after 56 days posttreatment. Again, no further release was observed after 70 days when 84 percent of the fluridone had been released into natural pond water.

The amounts of fluridone remaining in the fiber formulation at the end of the experiment on Day 104 were determined by extracting the fiber in methanol. A total recovery of 96 percent and 98 percent was obtained for treatments in reconstituted water and in natural water, respectively, indicating that degradation of fluridone was minimal under our experimental conditions. The amount of fluridone remaining in the fiber formulation was significantly higher in treatments with natural water (14 percent in treatments with natural water versus 6 percent with reconstituted water), suggesting that the difference in release rates observed in the two types of water (Figure 3) may be real.

Fluridone fiber in flowing water and efficacy against hydrilla. An average release rate of 4.3 mg fluridone/g fiber/day was calculated for the fluridone formulation based on results of cumulative release *in static tests* (Figure 3). Treatments were then made to maintain levels from 0.01 to 0.10 mg/ℓ fluridone in the flowing water in culture vessels previously established with hydrilla. The experiment was conducted in a glass greenhouse under 80 percent sunlight.

Concentrations of fluridone in the flowing water stabilized around the desired treatment levels by 7 days posttreatment; however, levels continued to decline in later sampling periods (Table 14). By Day 42, fluridone concentrations were about half of the expected levels. The presence of plants and soil in the experimental system had no significant effect on the herbicide concentrations in the flowing water.

Typical discoloration of the hydrilla tips was observed as early as 3 days after fluridone treatment; however, mature plant tissues remained healthy and injury ratings stayed below 30 percent through the end of the 7-week experiment. Previous studies indicated that fluridone has slow activity, and weed control was not achieved until after 12 weeks posttreatment under our experimental conditions.

Regrowth from rootstocks was observed in all treatments and the emerging shoots continued to elongate in vessels receiving low treatment rates (Table 15). However, the young shoots emerging from rootstocks never grew more than 4 cm long in treatments where fluridone concentrations were maintained at levels of 0.04 mg/ℓ or higher. Significant reductions in both shoot and root dry weights

Table 14

Measured Release of Fluridone from Monolithic Fibers in Flowing Natural Water

Treat-ment No.	Fluridone Treatment*	*Fluridone (mg/l) at Days Posttreatment***						
		1	3	7	14	21	28	42
I	0.01 mg/l, with plants	0.016 ±0.002	0.022 ±0.001	0.012 ±0.002	0.008 ±0.003	0.004 ±0.002	0.006 ±0.001	0.005 ±0.001
II	0.02 mg/l, with plants	0.032 ±0.004	0.050 ±0.003	0.027 ±0.002	0.016 ±0.002	0.008 ±0.001	0.010 ±0.003	0.007 ±0.001
III	0.05 mg/l, with plants	0.100 ±0.004	0.109 ±0.010	0.054 ±0.002	0.035 ±0.004	0.020 ±0.006	0.026 ±0.001	0.026 ±0.004
IV	0.10 mg/l, with plants	0.202 ±0.012	0.293 ±0.052	0.105 ±0.005	0.073 ±0.007	0.041 ±0.005	0.043 ±0.006	0.054 ±0.018
V	0.10 mg/l, no plants	0.197 ±0.028	0.283 ±0.014	0.118 ±0.005	0.057 ±0.002	0.028 ±0.003	0.035 ±0.004	0.049 ±0.006

* Total treatment, assuming complete chemical release, equals to 0.42, 0.82, 2.05, 4.07, and 3.81 mg/l fluridone in treatments I, II, III, IV, and V, respectively.

** Means of four replicates ± standard error.

Table 15

Effect of Fluridone Released from Monolithic Fibers on Mature Hydrilla and on Regrowth from Rootstocks after 7 weeks in Flowing Water*

Fluridone Treatment	*Mature Plants*				*Regrowth from Rootstocks*			
	Shoot Length cm	Shoot Weight g	Root Weight g	Root/Shoot Ratio	Shoot Length cm	Shoot Weight g	Root Weight g	Root/Shoot Ratio
Control	65[a]	9.93[a]	0.41[a]	0.04	27[a]	1.06[a]	0.10[a]	0.10
0.01 mg/l	80[a]	5.86[b]	0.02[b]	0.03	18[ab]	0.44[b]	0.08[ab]	0.18
0.02 mg/l	99[a]	5.10[b]	0.23[b]	0.05	15[b]	0.42[b]	0.06[bc]	0.14
0.05 mg/l	63[a]	5.76[b]	0.15[b]	0.03	17[ab]	0.50[b]	0.06[abc]	0.12
0.10 mg/l	59[a]	5.86[c]	0.17[b]	0.03	4[c]	0.51[b]	0.05[c]	0.11

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicates.

were obtained after 7 weeks (Table 15); however, no differences in dry weights were observed among the different treatment rates.

Evaluation of Conventional Formulations

Hydrilla tuber germination, tuber formation. Several herbicides were evaluated in the laboratory for inhibition of hydrilla tuber germination, as well as for phytotoxicity towards any new sprouts emerging from the germinated tubers.

Dichlobenil applied up to 1.0 mg/l did not inhibit hydrilla tuber germination (Table 16). However, growth and development of the newly germinating sprouts were severely retarded by a treatment of 0.05 mg/l dichlobenil. Furthermore, treatments of 0.10 mg/l or higher produced 87 percent or greater injury ratings to the germinated plants.

Table 16
Effect of Dichlobenil on Hydrilla Regrowth from Tubers*

Treatments *mg/l*	*Germination* %	*Shoot Length* *cm*	*Plant Dry Weight* *g*	*Injury* %
		Experiment 1		
Control	44^{a}	31.0^{a}	—	3
0.25	66^{a}	0^{b}	—	100
0.5	56^{a}	0^{b}	—	100
1.0	44^{a}	0^{b}	—	100
		Experiment 2		
Control	52^{a}	25.1^{a}	0.602^{a}	0
0.05	37^{a}	6.5^{b}	0.258^{b}	33
0.10	42^{a}	4.9^{c}	0.030^{c}	87
0.25	37^{a}	3.3^{c}	0.009^{c}	97
0.50	33^{a}	2.3^{c}	0.003^{c}	98

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicated jars.

Fluridone effectively retarded hydrilla regrowth at the 0.01 mg/*l* treatment rate (Table 17). However, concentrations up to 0.10 mg/*l* produced less than 57 percent injury ratings to the germinated plants after 8 weeks. There was a sustained loss of chlorophyll in the young meristematic tissues from the beginning of the test through termination, but no other injury was evident. Tuber germination was not affected by fluridone treatments up to 0.10 mg/*l*.

Hydrilla regrowth appeared most sensitive to treatments with DPX-5648. Concentrations of 0.001 mg/*l* or higher effected significant reductions in growth

Table 17
Effect of Fluridone on Hydrilla Regrowth from Tubers*

Treatments *mg/l*	*Germination* %	*Shoot Length* *cm*	*Plant Dry Weight* *g*	*Injury* %
		Experiment 1		
Control	52^{a}	24.3^{a}	0.700^{a}	0
0.01	47^{a}	20.2^{ab}	0.181^{b}	37
0.025	38^{a}	16.0^{ab}	0.119^{b}	50
0.05	45^{a}	13.2^{b}	0.139^{b}	40
0.10	45^{a}	10.5^{b}	0.123^{b}	57
		Experiment 2		
Control	—	24.6^{ab}	0.702^{a}	0
0.001	—	30.0^{a}	0.760^{a}	7
0.005	—	19.3^{bc}	0.110^{b}	50
0.010	—	22.7^{abc}	0.067^{b}	50
0.050	—	14.0^{c}	0.050^{b}	53

* Values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicated jars.

in stem lengths as well as in dry weights (Table 18). Root growth was severely inhibited by the DPX-5648 treatments, suggesting that the chemical might be translocated readily throughout the plant tissues. DPX-5648 produced little phytotoxic effect, however, to the new shoots emerging from germinated tubers.

The growth retardant PP-333 also produced little evidence of phytotoxicity toward hydrilla regrowth. The highest treatment rate (2.0 mg/l) did not effect injury to the test plants. However, concentrations of 1.0 mg/l or higher significantly retarded hydrilla regrowth from tubers (Table 18).

In a comparative study, the effects of several herbicides on new growth emerging from germinated tubers of hydrilla and sago pondweed were investigated. From these evaluation results (Tables 19 and 20) and results of other studies (Tables 16-18), the minimum herbicide concentrations required for control of regrowth in hydrilla and sago pondweed were determined.

For dichlobenil, a threshold level between 0.05 and 0.10 mg/l appeared to be required for control of regrowth from hydrilla tubers (Table 19). Also, regrowth from sago pondweed tubers was effectively controlled at 0.10 mg/l dichlobenil (Table 20).

Similarly, a minimum concentration of 0.01 to 0.05 mg/l fluridone was required to control regrowth from tubers in both hydrilla and sago pondweed.

Significant increases in phytotoxicity to the young hydra sprouts were observed when treatments of fluridone were made under higher light intensities. Injury ratings of 93 percent for hydrilla (Table 19) and 97 percent for sago pondweed (Table 20) were obtained when 0.05 mg/l fluridone was applied under a radiant flux of 200 $\mu E/m^2/sec$. Similar fluridone treatments made under 40 $\mu E/m^2/sec$ produced only 40 to 53 percent injury ratings (Table 17).

DPX-5648 appeared to be effective against regrowth of both hydrilla and sago pondweed at treatment rates as low as 0.001 to 0.005 mg/l.

Submersed weeds. N-252 and S-734 were evaluated in the laboratory for efficacy in controlling hydrilla, watermilfoil, naiad, and chara (Tables 21 and 22), cabomba, coontail, lemon bacopa, and hygrophila (Tables 23 and 24).

Treatments of S-734 at rates up to 5.0 mg/l produced little damage to the test plants. The results of evaluation against watermilfoil and cabomba were confounded by high injury ratings of control plants.

In contrast, N-252 was effective against most of the submersed aquatic species tested after 8 weeks at treatment rates of 1.0 mg/l or higher. Control of lemon bacopa and hygrophila was not achieved, however, until an impractical treatment rate of 5.0 mg/l was applied. These two species were found previously to be more tolerant to most aquatic herbicides currently available.

The evaluations of AC-925 and AC-214 for potential use in management of aquatic plants are complete. The two chemicals are generally not effective against submersed aquatic weeds (Tables 25 and 26). In the tests they produced moderate control of coontail, naiad, hygrophila, watermilfoil, and hydrilla at the

Table 18
Effect of DPX-5648 and PP-333 on Hydrilla Regrowth from Tubers*

Treatments mg/l	Germination %	Shoot Length cm	Dry Weight Shoot g	Dry Weight Root g	Injury %
		Experiment 1			
Control	53^{a}	34.5^{a}	0.750^{a}	0.130^{a}	10
0.001 DPX-5648	40^{a}	8.1^{b}	0.265^{b}	0.010^{b}	23
0.005 DPX-5648	54^{a}	4.4^{b}	0.260^{b}	0^{b}	20
0.010 DPX-5648	44^{a}	4.6^{b}	0.255^{b}	0^{b}	18
0.025 DPX-5648	50^{a}	4.4^{b}	0.237^{b}	0^{b}	17
0.050 DPX-5648	52^{a}	4.2^{b}	0.222^{b}	0^{b}	20
		Experiment 2			
Control	53^{a}	34.5^{a}	0.750^{a}	0.130^{a}	10
0.25 PP-333	47^{a}	15.4^{b}	0.748^{a}	0.107^{ab}	10
0.5 PP-333	67^{a}	9.3^{c}	0.655^{a}	0.091^{ab}	20
1.0 PP-333	53^{a}	6.7^{d}	0.496^{b}	0.077^{bc}	13
2.0 PP-333	43^{a}	4.6^{d}	0.345^{c}	0.039^{c}	20

* For each chemical, values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicated jars.

Table 19
Effects of Various Chemicals on Hydrilla Regrowth from Tubers*

Treatments mg/l	Survival %	Shoot Length cm	Dry Weight Shoot g	Dry Weight Root g	Injury %
		Dichlobenil			
Control	100^{a}	24.0^{a}	0.660^{a}	0.060^{a}	0
0.025	100^{a}	23.3^{ab}	0.597^{a}	0.052^{a}	3
0.05	96^{a}	18.7^{ab}	0.403^{b}	0.035^{b}	17
0.10	100^{a}	16.3^{b}	0.327^{c}	0.013^{c}	77
0.25	54^{b}	4.0^{c}	0.038^{d}	0	95
		Fluridone			
Control	100^{a}	24.0^{ab}	0.660^{a}	0.060^{a}	0
0.001	96^{ab}	30.0^{a}	0.117^{a}	0.045^{b}	7
0.005	88^{ab}	19.3^{bc}	0.095^{b}	0.016^{c}	50
0.010	50^{c}	22.7^{abc}	0.060^{b}	0.007^{c}	70
0.050	66^{bc}	14.0^{c}	0.044^{b}	0.006^{c}	93
		DPX-5648			
Control	100^{a}	24.0^{ab}	0.660^{a}	0.060^{a}	0
0.0002	100^{a}	27.3^{a}	0.652^{a}	0.063^{a}	0
0.0005	100^{a}	27.3^{a}	0.630^{a}	0.052^{a}	0
0.001	100^{a}	19.7^{bc}	0.546^{ab}	0.020^{b}	17
0.005	100^{a}	13.0^{c}	0.292^{b}	0.010^{b}	17
		Fenac			
Control	100^{a}	24.0^{ab}	0.660^{ab}	0.060^{b}	0
0.025	100^{a}	28.7^{a}	0.694^{a}	0.051^{b}	0
0.05	100^{a}	25.7^{a}	0.677^{a}	0.068^{b}	0
0.10	100^{a}	21.7^{b}	0.474^{b}	0.140^{a}	30
0.25	91^{a}	2.3^{c}	0.028^{c}	0.149^{a}	73

* For each chemical, values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicated jars.

Table 20
Effect of Various Chemicals on Sago Pondweed Regrowth from Tubers*

Treatments mg/l	Survival %	Shoot Length cm	Dry Weight Shoot g	Dry Weight Root g	Injury %
		Dichlobenil			
Control	100[a]	47.3[a]	0.353[a]	0.025[b]	0
0.025	83[a]	35.0[a]	0.334[a]	0.048[a]	3
0.05	83[a]	35.7[a]	0.279[a]	0.025[b]	17
0.10	8[b]	3.3[b]	0.006[b]	0[c]	88
0.25	0[b]	0[b]	0[b]	0[c]	93
		Fluridone			
Control	100[a]	47.3[a]	0.353[ab]	0.025[ab]	0
0.001	93[a]	44.7[a]	0.351[ab]	0.039[a]	0
0.005	93[a]	38.0[a]	0.446[ab]	0.028[a]	60
0.010	75[b]	34.0[a]	0.182[bc]	0.006[bc]	60
0.050	0[c]	0[b]	0[b]	0[c]	97
		DPX-5648			
Control	100[a]	47.3[a]	0.353[a]	0.025[a]	0
0.0002	93[a]	33.7[ab]	0.374[a]	0.008[b]	0
0.0005	75[a]	26.7[bc]	0.302[a]	0[c]	17
0.0001	100[a]	15.7[bc]	0.330[a]	0.002[c]	20
0.005	100[a]	13.7[c]	0.191[b]	0[c]	17
		Fenac			
Control	100[a]	47.3[a]	0.353[a]	0.025[a]	0
0.025	100[a]	32.3[ab]	0.412[a]	0.018[a]	0
0.05	75[ab]	26.3[b]	0.243[b]	0.025[a]	0
0.10	68[b]	26.3[b]	0.090[c]	0[b]	50
0.25	33[c]	2.7[c]	0.016[c]	0[b]	88

* For each chemical, values in a column followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test. Each value is the mean of four replicated jars.

Table 21
Laboratory Evaluations of N-252 for Phytotoxicity
Toward Hydrilla (H), Watermilfoil (W), Naiad (N), and Chara (CR), 3 June 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			1 week				2 weeks				4 weeks			
			H	W	N	CR	H	W	N	CR	H	W	N	CR
N-252	Uniroyal	0.25	3	5	0	0	5	7	2	0	5	40	5	7
		0.5	0	3	0	0	0	7	2	0	0	10	8	7
		1.0	0	23	0	0	17	75	25	2	37	75	70	63
		5.0	20	50	20	7	90	90	83	70	100	100	100	100
Control			0	10	0	7	10	30	0	5	10	37	0	10
			6 weeks				8 weeks				10 weeks			
			H	W	N	CR	H	W	N	CR	H	W	N	CR
N-252	Uniroyal	0.25	5	40	5	8	20	67	20	33	20	57	20	40
		0.5	10	13	30	20	13	30	23	53	13	37	23	57
		1.0	67	90	90	98	97	100	98	98	95	100	100	100
		5.0	100	100	100	100	100	100	100	100	100	100	100	100
Control			7	33	0	10	3	40	0	10	0	43	0	13

* Average of three replicates.

Table 22
Laboratory Evaluations of S-734 for Phytotoxicity
Toward Hydrilla (H), Watermilfoil (W), Naiad (N), and Chara (CR), 3 June 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			1 week				2 weeks				4 weeks			
			H	W	N	CR	H	W	N	CR	H	W	N	CR
S-734	Uniroyal	0.25	0	0	0	0	0	3	0	0	7	30	10	17
		0.5	0	0	0	3	3	5	3	0	8	20	7	8
		1.0	0	0	2	0	0	5	0	0	0	5	0	0
		5.0	3	0	3	2	0	13	5	0	3	47	7	3
	Control		0	10	0	7	10	30	0	5	10	37	0	10
			6 weeks				8 weeks				10 weeks			
			H	W	N	CR	H	W	N	CR	H	W	N	CR
S-734	Uniroyal	0.25	7	47	7	17	18	40	8	17	20	42	12	20
		0.5	12	57	7	15	10	53	12	13	13	53	13	15
		1.0	3	17	3	3	3	37	12	3	3	37	10	17
		5.0	7	100	13	3	17	100	33	3	13	100	33	10
	Control		7	33	0	10	3	40	0	10	0	43	0	13

* Average of three replicates.

Table 23

Laboratory Evaluations of N-252 for Phytotoxicity Toward
Cabomba (CA), Coontail (CT), Bacopa (B), and Hygrophila (HP), 3 June 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			1 week				2 weeks				4 weeks			
			CA	CT	B	HP	CA	CT	B	HP	CA	CT	B	HP
N-252	Uniroyal	0.25	7	2	0	0	8	5	10	7	23	10	10	10
		0.5	0	2	0	0	25	5	10	10	40	17	10	10
		1.0	5	5	0	2	50	18	17	15	87	33	17	12
		5.0	67	30	0	27	98	48	73	43	100	57	100	60
Control			17	0	0	0	20	2	5	10	43	3	7	10
			6 weeks				8 weeks				10 weeks			
			CA	CT	B	HP	CA	CT	B	HP	CA	CT	B	HP
N-252	Uniroyal	0.25	37	18	10	10	37	25	10	10	43	27	10	10
		0.5	50	22	10	10	50	42	13	8	47	28	10	8
		1.0	100	72	20	27	100	72	22	27	100	70	27	43
		5.0	100	93	100	97	100	98	100	100	100	98	100	100
Control			43	5	7	10	43	5	7	10	43	5	7	10

* Average of three replicates.

Table 24

Laboratory Evaluations of S-734 for Phytotoxicity Toward
Cabomba (CA), Coontail (CT), Bacopa (B), and Hygrophila (HP), 3 June 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			1 week				2 weeks				4 weeks			
			CA	CT	B	HP	CA	CT	B	HP	CA	CT	B	HP
S-734	Uniroyal	0.25	3	0	0	0	3	0	0	10	0	0	0	20
		0.5	8	0	0	0	17	3	2	8	47	3	3	13
		1.0	13	0	0	3	33	0	5	13	40	7	2	10
		5.0	0	3	0	7	33	0	7	12	40	7	5	20
	Control		17	0	0	0	20	2	5	10	43	3	7	10
			6 weeks				8 weeks				10 weeks			
			CA	CT	B	HP	CA	CT	B	HP	CA	CT	B	HP
S-734	Uniroyal	0.25	7	0	0	23	13	7	3	30	33	8	3	37
		0.5	90	5	5	12	80	3	5	25	93	3	0	30
		1.0	47	7	3	8	70	3	3	8	67	0	0	20
		5.0	50	7	5	37	77	7	5	42	90	7	5	43
	Control		43	5	7	10	43	5	7	10	43	5	7	10

* Average of three replicates.

Table 25
Laboratory Evaluations of AC-925 and AC-214 for Phytotoxicity Toward Combined Hydrilla (H), Watermilfoil (W), Bacopa (B), and Chara (CR), 17 March 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			2 weeks				4 weeks				6 weeks			
			H	W	B	CR	H	W	B	CR	H	W	B	CR
AC-925	American	0.25	3	3	0	0	3	3	0	0	3	8	0	0
	Cyanamid	0.50	0	3	0	0	2	25	0	0	2	57	0	5
		1.0	5	7	0	0	10	13	0	0	13	20	0	3
		5.0	15	23	0	0	23	40	0	0	30	53	0	0
	Control		0	2	0	0	0	2	0	0	2	5	0	3
			8 weeks				10 weeks				12 weeks			
			H	W	B	CR	H	W	B	CR	H	W	B	CR
AC-925	American	0.25	10	17	2	10	13	20	2	18	17	20	2	27
	Cyanamid	0.50	7	57	0	12	10	70	0	17	13	77	0	17
		1.0	17	37	0	10	22	60	3	20	23	75	3	23
		5.0	52	63	0	8	73	80	0	12	70	90	0	17
	Control		7	8	0	8	13	5	0	13	20	7	0	13
			2 weeks				4 weeks				6 weeks			
			H	W	B	CR	H	W	B	CR	H	W	B	CR
AC-214	American	0.25	0	2	0	0	2	7	2	0	3	37	0	3
	Cyanamid	0.50	5	17	0	0	3	30	0	2	7	40	0	3
		1.0	7	10	0	0	10	33	0	0	30	62	0	0
		5.0	10	30	0	0	10	43	0	0	22	67	2	5
	Control		0	2	0	0	0	2	0	0	2	5	0	3
			8 weeks				10 weeks				12 weeks			
			H	W	B	CR	H	W	B	CR	H	W	B	CR
AC-214	American	0.25	3	37	0	13	12	38	0	13	13	35	0	18
	Cyanamid	0.50	12	40	0	5	13	50	0	20	13	53	0	13
		1.0	33	80	0	5	50	90	7	13	53	88	37	13
		5.0	90	67	20	10	92	73	27	13	93	77	30	13
	Control		7	8	0	8	13	5	0	13	20	7	0	13

* Average of three replicates.

Table 26
Laboratory Evaluations of AC-925 and AC-214 for Phytotoxicity Toward Combined Cabomba (CA), Coontail (CT), Naiad (N), and Hygrophila (HP), 17 March 1982

Chemical Designation	Company or Source	Rate mg/l	Posttreatment Control, percent*											
			2 weeks				4 weeks				6 weeks			
			CA	CT	N	HP	CA	CT	N	HP	CA	CT	N	HP
AC-925	American	0.25	2	0	0	0	28	0	0	10	43	0	3	10
	Cyanamid	0.50	8	0	0	0	53	0	3	10	70	8	0	13
		1.0	2	0	0	0	18	7	0	10	37	33	13	30
		5.0	5	0	0	3	27	20	2	17	32	33	8	43
	Control		2	0	0	0	10	0	0	0	12	0	0	0
			8 weeks				10 weeks				12 weeks			
			CA	CT	N	HP	CA	CT	N	HP	CA	CT	N	HP
AC-925	American	0.25	50	7	13	13	50	17	17	23	57	20	23	30
	Cyanamid	0.50	73	17	5	17	70	30	8	20	60	40	8	23
		1.0	37	33	17	37	57	55	23	57	63	68	42	57
		5.0	40	50	27	60	63	82	60	83	80	92	93	92
	Control		18	0	0	17	30	0	3	20	40	0	0	23
			2 weeks				4 weeks				6 weeks			
			CA	CT	N	HP	CA	CT	N	HP	CA	CT	N	HP
AC-214	American	0.25	0	0	0	0	13	2	0	10	20	8	3	20
	Cyanamid	0.50	2	0	0	3	10	8	0	10	17	18	0	23
		1.0	8	7	3	0	27	23	10	8	23	43	33	20
		5.0	0	0	0	0	43	13	2	20	60	23	25	27
	Control		2	0	0	0	10	0	0	0	12	0	0	0
			8 weeks				10 weeks				12 weeks			
			CA	CT	N	HP	CA	CT	N	HP	CA	CT	N	HP
AC-214	American	0.25	22	20	3	20	33	23	3	17	40	30	7	20
	Cyanamid	0.50	27	25	2	20	45	47	10	23	42	50	15	23
		1.0	43	60	40	33	77	75	47	40	77	88	65	40
		5.0	60	55	55	60	55	85	63	85	55	93	90	95
	Control		18	0	0	17	30	0	3	20	40	0	0	23

* Average of three replicates.

treatment rate of 5.0 mg/ℓ. This rate is generally considered to be economically infeasible for field application. Chara was not controlled by either chemical at treatment rates up to 5.0 mg/ℓ.

PP-333 was not effective as an aquatic herbicide when evaluated against mature, established submersed aquatic plants (Table 27). The highest treatment rate (5.0 mg/ℓ) did not effect significant injury to any of the test species. PP-333 acts, however, as a growth retardant which significantly reduced hydrilla regrowth from tubers (Table 8) and waterhyacinth biomass.

Table 27

Laboratory Evaluations of PP-333 for Phytotoxicity Toward Combined Hydrilla (H), Watermilfoil (W), Bacopa (B), and Chara (CR), 29 June 1982

			*Posttreatment Control, percent**											
			1 week				*2 weeks*				*4 weeks*			
Chemical Designation	*Company or Source*	*Rate mg/l*	*H*	*W*	*B*	*CR*	*H*	*W*	*B*	*CR*	*H*	*W*	*B*	*CR*
PP-333	ICI	0.5	0	0	0	0	0	0	0	0	0	0	7	0
		1.0	0	0	0	0	0	0	0	0	0	0	0	0
		2.0	0	0	0	0	0	0	0	0	0	0	0	0
		5.0	0	0	0	0	0	0	0	0	0	0	0	0
	Control		0	0	0	0	0	0	0	0	0	0	0	0
			6 weeks				*8 weeks*				*10 weeks*			
			H	*W*	*B*	*CR*	*H*	*W*	*B*	*CR*	*H*	*W*	*B*	*CR*
PP-333	ICI	0.5	0	0	7	0	0	0	7	0	0	3	10	0
		1.0	0	0	0	0	0	0	0	0	0	10	0	0
		2.0	0	0	0	0	0	0	0	0	3	7	0	7
		5.0	7	3	7	10	10	17	20	70	17	17	17	72
	Control		0	0	0	0	0	0	0	0	7	7	0	0
			1 week				*2 weeks*				*4 weeks*			
			CA	*N*	*E*	*HP*	*CA*	*N*	*E*	*HP*	*CA*	*N*	*E*	*HP*
PP-333	ICI	0.5	0	0	0	0	0	0	0	3	0	0	0	0
		1.0	0	0	0	0	0	0	0	7	0	0	0	0
		2.0	0	0	0	0	0	0	0	7	0	0	0	0
		5.0	0	0	0	3	0	0	0	3	0	0	0	3
	Control		0	0	0	0	0	0	0	7	0	0	0	3
			6 weeks				*8 weeks*				*10 weeks*			
			CA	*N*	*E*	*HP*	*CA*	*N*	*E*	*HP*	*CA*	*N*	*E*	*HP*
PP-333	ICI	0.5	7	0	0	0	40	0	7	0	43	0	0	7
		1.0	0	0	0	0	17	0	0	0	33	0	0	10
		2.0	7	0	0	0	13	0	3	0	17	0	3	7
		5.0	7	7	3	7	40	10	17	37	50	20	17	30
	Control		7	0	0	0	17	3	0	0	53	3	0	3

* Average of three replicates.

The response of hydrilla to combinations of diquat and Cide Kick was not different than to diquat alone after 10 weeks posttreatment (Table 28). Cide Kick appeared, however, to speed up the phytotoxic response to diquat as reflected by increased injury ratings at 4 to 6 weeks after treatments. There was no difference in hydrilla response to the diquat and Cide Kick combinations, when concentration of Cide Kick was increased from 1 to 3 ppm.

Lemon bacopa. Susceptibility of lemon bacopa to aquatic herbicides now available or under development was determined (Table 29).

Lemon bacopa was most sensitive to diquat and terbutryn with complete control obtained at all treatment rates from 0.63 to 5.0 mg/ℓ after 4 weeks posttreatment.

Diuron and fenac produced 100 percent control at a treatment rate of 1.25 mg/ℓ after 6 weeks and 10 weeks, respectively.

Dichlobenil appeared effective in lemon bacopa at a treatment rate of 1.25 mg/ℓ, which produced 97 percent control after 10 weeks.

Simazine effected 100 percent control of lemon bacopa after 8 weeks at a treatment rate of 2.5 mg/ℓ or higher.

On the other hand, lemon bacopa appeared to be tolerant to many herbicides now widely used for control of submersed aquatic plants.

Both copper ethylenediamine complex (Komeen®) and potassium endothall were found ineffective at treatment rates up to 5.0 mg/ℓ.

The liquid endothall amine was effective at rates between 2.5 and 5.0 mg/ℓ 4 weeks after treatment. However, high fish toxicity may present a problem at these treatment rates.

Floating weeds. Both the experimental herbicides N-252 and S-734 were effective against waterhyacinth at the treatment rate of 5.6 kg/ha (Table 30).

Water lettuce was more sensitive to N-252 and S-734, with complete control obtained at treatment rates of 2.24 and 1.12 kg/ha, respectively (Table 30).

Efficacy tests for AC-925 and AC-214 were conducted against several floating and emergent species. Complete control of waterhyacinth and water lettuce was obtained with all treatment rates from 0.56 to 5.6 kg/ha of AC-925 and AC-214 (Table 31).

In a second series of tests with lower treatment rates (Table 32), AC-214 produced 100 percent control of waterhyacinth and water lettuce at 0.28 kg/ha and 0.112 kg/ha, respectively, after 10 weeks posttreatment. AC-925 appeared equally effective against waterhyacinth and water lettuce at approximately the same treatment rates (Table 32).

PP-333 acted as a growth retardant and significantly reduced plant biomass after 6 weeks at the treatment rate 1.112 kg/ha (Table 33).

Glyphosate (Scout®) was found effective against waterhyacinth after 4 weeks at treatment rates 2.8 kg a.e./ha or higher in an outdoor pool experiment (Table 34).

Table 28

Herbicidal Activity of Diquat on Hydrilla Applied With and Without the Additive Cide Kick

Treatment	Rate, mg/l	Percent Injury at Weeks Posttreatment*					
		1	2	4	6	8	10
Cide Kick	1.0	10 ±6	7 ±3	17± 3	15 ± 0	15 ± 0	10 ± 0
Cide Kick	2.0	20 ± 10	15 ± 4	25 ± 4	25 ± 4	23 ± 2	18 ± 2
Cide Kick	3.0	7 ± 3	10 ± 0	23 ± 9	15 ± 0	13 ± 2	7 ± 3
Diquat	0.2	17 ± 7	13 ± 9	47 ± 3	55 ± 8	80 ± 3	82 ± 2
Diquat + Cide Kick	0.2 + 1.0	20 ± 0	37 ± 17	63 ± 13	83 ± 7	88 ± 3	85 ± 9
Diquat + Cide Kick	0.2 + 2.0	20 ± 6	20 ± 6	60 ± 6	85 ± 5	87 ± 4	83 ± 3
Diquat + Cide Kick	0.2 + 3.0	23 ± 7	20 ± 0	67 ± 3	85 ± 3	88 ± 3	85 ± 3
Control	0	0 ± 0	3 ± 3	17 ± 3	17 ± 3	17 ± 3	13 ± 2

* Average of three replicates ± S.E.

Table 29

Laboratory Evaluations of Several Aquatic Herbicides for Efficacy Towards Lemon Bacopa

Chemical Treatment Rate mg/l	Percent Injury at Weeks Posttreatment*					
	2	3	4	6	8	10
Copper EDA**						
1.25	0	-	7	13	20	10
2.50	0	-	23	30	30	35
5.00	0	-	20	30	53	62
Dicamba + 2,4-D						
1.25	30	30	37	27	27	23
2.50	27	27	33	47	43	50
5.00	27	40	65	90	92	92
Dichlobenil						
1.25	15	17	23	73	93	97
2.50	12	18	58	75	92	95
5.00	8	8	28	88	97	97
Diquat						
0.63	10	-	100	100	100	100
1.25	17	-	100	100	100	100
2.50	10	-	100	100	100	100
5.00	20	-	100	100	100	100
Diuron						
1.25	17	47	97	100	100	100
2.50	40	53	97	100	100	100
5.00	13	60	100	100	100	100
Endothallamine (pellet)						
0.63	10	-	20	20	17	33
1.25	7	-	17	17	18	20
2.50	10	-	23	23	20	23
5.00	10	-	73	80	73	75
Endothallamine (liquid)						
0.63	27	27	37	37	30	23
1.25	30	33	65	70	60	52
2.50	20	60	97	93	87	83
5.00	43	87	100	100	100	100
Endothallamine (System L)						
1.25	20	20	23	33	17	23
2.50	24	30	30	30	37	27
5.00	8	13	23	33	23	18
Potassium Endothall						
1.25	7	-	13	10	12	6
2.50	10	-	13	17	8	9
5.00	7	-	23	20	23	25
Fenac						
1.25	8	22	63	85	98	100
2.50	17	57	98	100	100	100
5.00	20	70	97	100	100	100
Fluridone						
1.25	22	22	25	22	28	25
2.50	8	8	15	12	12	15
5.00	17	17	20	20	23	28
Simazine						
1.25	15	20	23	48	53	63
2.50	17	30	88	98	100	100
5.00	37	47	96	100	100	100
Terbutryn						
0.63	15	63	100	100	100	100
1.25	37	77	100	100	100	100
2.50	83	93	100	100	100	100
5.00	20	67	100	100	100	100
2,4-D DMA†						
1.25	13	13	13	13	12	10
2.50	23	40	78	98	92	87
5.00	20	43	83	83	90	80
Control	22	17	18	15	13	7

* Average of three replicates.

** Ethylene diamine complex.

† Dimethylamine salt.

Table 30
Greenhouse Evaluation of N-252 and S-734 for
Phytotoxicity Toward Floating Weeds, 2 August 1982

Chemical Designation	Company or Source	Rate kg/ha	Percent Injury at Weeks Posttreatment*					
			1	2	4	6	8	10
			Waterhyacinth					
N-252	Uniroyal	0.56	20	10	10	7	13	23
		1.12	23	20	18	30	43	53
		2.24	43	63	63	40	60	60
		5.60	72	92	97	90	87	100
S-734	Uniroyal	0.56	3	3	7	7	10	0
		1.12	7	12	25	33	47	27
		2.24	10	23	52	70	60	82
		5.60	13	18	57	83	85	95
	Control		0	10	10	0	0	0
			Water Lettuce					
N-252	Uniroyal	0.56	17	10	7	7	7	10
		1.12	38	57	53	47	37	57
		2.24	85	100	100	100	100	100
		5.60	100	100	100	100	100	100
S-734	Uniroyal	0.56	13	23	53	57	60	63
		1.12	18	33	88	93	98	100
		2.26	18	35	92	95	90	90
		5.60	18	43	95	98	100	100
	Control		0	0	0	0	0	0

* Average of three replicates.

Table 31
Greenhouse Evaluation of AC-925 and AC-214 for
Phytotoxicity Toward Floating Weeds, 22 March 1982

Chemical Designation	Company or Source	Rate kg/ha	Percent Injury at Weeks Posttreatment*				
			1	2	4	6	8
			Waterhyacinth				
AC-925	American	0.56	8	20	83	95	97
	Cyanamid	1.12	10	25	83	95	97
		2.24	8	22	87	97	97
		5.60	13	25	82	93	100
AC-214	American	0.56	7	13	45	88	88
	Cyanamid	1.12	10	13	88	95	97
		2.24	10	25	93	98	100
		5.60	20	35	95	100	100
	Control		3	5	13	22	13
			Water Lettuce				
AC-925	American	0.56	7	25	93	100	100
	Cyanamid	1.12	13	28	97	100	100
		2.24	12	23	93	95	100
		5.60	22	30	95	100	100
AC-214	American	0.56	13	15	83	98	100
	Cyanamid	1.12	7	15	93	97	100
		2.24	18	22	83	98	100
		5.60	20	25	100	100	100
	Control		2	2	2	0	15

* Average of three replicates.

Table 32

Greenhouse Evaluation of AC-925 and AC-214 for Phytotoxicity Toward Floating Weeds, 22 July 1982

Chemical Designation	Company or Source	Rate kg/ha	Percent Injury at Weeks Posttreatment*					
			1	2	4	6	8	10
			Waterhyacinth					
AC-925	American	0.056	13	13	27	62	68	80
	Cyanamid	0.112	17	30	67	93	95	97
		0.280	25	28	73	95	98	100
		0.560	25	33	73	97	98	100
AC-214	American	0.056	12	17	35	83	85	95
	Cyanamid	0.112	20	27	65	90	88	90
		0.280	33	43	83	97	98	100
		0.560	27	35	70	97	98	100
	Control		10	10	10	10	10	0
			Water Lettuce					
AC-925	American	0.056	50	90	100	100	100	100
	Cyanamid	0.112	40	67	92	95	92	75
		0.280	67	90	98	100	100	100
		0.560	37	70	97	100	100	100
AC-214	American	0.056	73	77	80	80	73	70
	Cyanamid	0.112	43	60	85	95	100	100
		0.280	23	67	93	100	100	100
		0.560	23	65	93	98	100	100
	Control		27	10	10	10	7	6

* Average of three replicates.

Table 33

Greenhouse Evaluation of PP-333 for Phytotoxicity Toward Waterhyacinth, 8 June 1982

Chemical Designation	Company or Source	Rate kg/ha	Percent Injury at Weeks Posttreatment*				Wet Weight After 6 Weeks**
			1	2	4	6	
PP-333	ICI	0.112	12	13	13	13	438^{ab}
(WP50)		0.280	12	12	12	13	425^{ab}
		0.560	10	13	15	15	470^{ab}
		1.120	22	28	27	25	361^{b}
PP-333	ICI	0.112	13	20	18	23	450^{b}
(G-1)		0.280	18	22	17	17	448^{b}
		0.560	15	23	27	28	425^{b}
		1.120	12	17	13	13	375^{b}
	Control		8	10	10	10	553^{a}

* Average of three replicates.

** Values followed by the same letter are not significantly different at P = 0.05 as determined by Waller-Duncan test.

Table 34
Percent Control of Waterhyacinth Following Treatment with Glyphosate (Scout®) in Outdoor Pools

Glyphosate Treatment kg a.e./ha	*Percent Control at Weeks Posttreatment**						
	1	*2*	*4*	*6*	*8*	*10*	*12*
Control	0	0	0	7 ± 3	0	0	0
2.24	57 ± 3	53 ± 3	68 ± 6	73 ± 4	73 ± 4	72 ± 6	65 ± 8
2.80	73 ± 7	77 ± 3	93 ± 2	93 ± 2	93 ± 2	92 ± 2	93 ± 2
3.36	75 ± 3	80 ± 5	93 ± 2	92 ± 2	93 ± 2	95 ± 0	95 ± 0
3.92	82 ± 2	85 ± 3	93 ± 2	93 ± 2	95 ± 3	95 ± 3	95 ± 0
4.48	88 ± 2	88 ± 2	95 ± 0	95 ± 0	95 ± 0	95 ± 0	97 ± 2

NOTE: Experiment was initiated on 14 September 1982.
* Values are means of three replicates ± S.E.

Emergent weeds. Both N-252 and S-734 were not effective on torpedograss or alligatorweed at treatment rates up to 5.6 kg/ha (Table 35).

The threshold injury level for AC-925 against alligatorweed appeared to be 0.56 kg/ha treatment rate, which produced 92 and 100 percent injury ratings in two separate experiments (Tables 36 and 37).

AC-214 produced 97 percent control of alligatorweed at 2.24 kg/ha (Table 36). Lower treatment rates were not effective (Table 37).

No evidence of phytotoxicity was shown by torpedograss to treatments of AC-214 up to 5.6 kg/ha (Table 36).

On the other hand, AC-925 effected 95 percent control of torpedograss 10 weeks after treatment at the rate 0.28 kg/ha (Table 37).

Field evaluations. The herbicide DPX-5648 continued to give promising results in field evaluations. Complete control of waterhyacinth was obtained with field treatment rates of 20 or 20 g a.i/ha DPX-5648.

The herbicide action was slow. The plants treated with DPX-5648 did not appear to be affected by the chemical during the first 3 weeks, but during the next several weeks the leaves gradually turned brown and the plants slowly died. Early plant responses to DPX-5648 included complete inhibition of daughter plant production, discoloration as mild chlorosis starting in the youngest tissues, and a purpling or anthocyanin expression that developed in the vascular stem tissues.

The maximum effects of DPX-5648 took about 10 to 12 weeks to develop, but reinfestation after treatment appeared to be minimal. In fact, the treatment of 20 g a.i./ha on the 0.07-ha pond at Fort Lauderdale AREC completely eliminated waterhyacinth in the pond. No regrowth either of vegetative offshoots (daughter plants) or from seedlings has yet been observed after 6 months posttreatment.

Glyphosate (Scout®) gave complete control of waterhyacinth at the field treatment rate of 3.36 kg a.e./ha. The treated plants started to become necrotic as early as 1 week after treatment, and an injury rating of about 90 percent was

Table 35
Greenhouse Evaluation of N-252 and S-734 for Phytotoxicity Toward Emergent Weeds, 2 August 1982

Chemical Designation	*Company or Source*	*Rate kg/ha*	*Percent Injury at Weeks Posttreatment**					
			1	*2*	*4*	*6*	*8*	*10*
			Alligatorweed					
N-252	Uniroyal	0.56	23	40	30	27	23	23
		1.12	43	40	37	32	28	18
		2.24	50	57	57	60	50	27
		5.60	60	72	73	78	72	67
S-734	Uniroyal	0.56	0	0	0	7	20	30
		1.12	0	0	0	10	27	23
		2.24	3	0	3	10	10	10
		5.60	3	0	0	10	37	40
	Control		0	0	0	0	3	3
			Torpedograss					
N-252	Uniroyal	0.56	20	25	25	23	17	17
		1.12	28	37	37	37	27	23
		2.24	28	47	47	50	27	27
		5.60	40	47	53	53	40	37
S-734	Uniroyal	0.56	13	7	10	13	17	22
		1.12	3	5	12	17	17	15
		2.24	7	7	10	10	12	12
		5.60	0	3	12	12	8	13
	Control		0	0	10	13	15	17

* Average of three replicates.

Table 36
Greenhouse Evaluation of *AC-925 and AC-214 for* Phytotoxicity Toward Emergent Weeds, 22 March 1982

Chemical Designation	*Company or Source*	*Rate kg/ha*	*Percent Injury at Weeks Posttreatment**					
			1	*2*	*4*	*6*	*8*	*10*
			Alligatorweed					
AC-925	American	0.56	32	88	97	100	100	100
	Cyanamid	1.12	18	78	93	100	100	100
		2.24	42	87	100	100	100	100
		5.60	38	87	100	100	100	100
AC-214	American	0.56	13	22	30	48	55	83
	Cyanamid	1.12	15	35	48	45	37	75
		2.24	13	45	60	93	100	97
		5.60	25	58	65	85	97	100
	Control		2	3	7	10	7	18
			Torpedograss					
AC-925	American	0.56	18	20	50	60	70	90
	Cyanamid	1.12	13	25	60	60	85	90
		2.24	10	27	70	63	85	95
		5.60	18	30	58	65	93	95
AC-214	American	0.56	0	0	8	10	10	10
	Cyanamid	1.12	8	8	20	30	25	25
		2.24	4	4	10	20	10	10
		5.60	4	5	23	30	25	30
	Control		0	0	13	10	15	25

* Average of three replicates.

Table 37
Greenhouse Evaluation of AC-925 and AC-214 for Phytotoxicity Toward Emergent Weeds, 22 July 1982

Chemical Designation	*Company or Source*	*Rate kg/ha*	*Percent Injury at Weeks Posttreatment**					
			1	*2*	*4*	*6*	*8*	*10*
			Alligatorweed					
AC-925	American	0.056	0	7	7	10	13	20
	Cyanamid	0.112	10	25	47	43	47	57
		0.280	12	32	60	75	88	88
		0.560	10	32	70	85	90	92
AC-214	American	0.056	0	0	0	0	3	10
	Cyanamid	0.112	0	0	0	0	3	3
		0.280	0	3	3	0	7	10
		0.560	0	7	7	7	20	25
	Control		0	0	0	0	0	3
			Torpedograss					
AC-925	American	0.056	10	15	28	33	33	30
	Cyanamid	0.112	10	15	33	47	52	50
		0.280	12	18	50	67	90	95
		0.560	20	23	43	70	93	95

* Average of three replicates.

obtained within 1 month. The mat then sank giving over 90 percent open water in the treated plot by 3 months after treatment.

Evaluations of the field treatment of 0.28 kg/ha AC-925 on waterhyacinth are still in progress, but after 4 weeks the chemical produced only 50 percent control. AC-925 was observed to have slow activity in previous laboratory tests.

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APPENDIX A: SAMPLE ANALYSES FOR HERBICIDE RESIDUES

Herbicide Analyses Methods Development

Method development for evaluating controlled release formulations of fluridone, dichlobenil, and 2,4-D included sample preparation and quantitation of herbicide content by high pressure liquid chromatography (HPLC).

a. Determination of chromatographic conditions for analytical standards brought to volume in reconstituted water and in natural pond water.

b. Development of procedures for water sample preparation.

c. Determination of chromatographic conditions for the quantitation of herbicide release from various controlled release formulations.

d. Verification of identity of the herbicides recovered from controlled release formulations of dichlobenil, 2,4-D, and fluridone by thin layer chromatography, absorbance ratios, and/or method of addition.

APPARATUS:

- Liquid chromatograph (HPLC). Perkin Elmer Model Series 3B pump system with Rheodyne 7125 Injector and Perkin Elmer/HS-5 C-18 (reverse phase) column. Perkin Elmer LC 75 Variable wavelength detector and auto control
- Recorder integrators. Houston Instruments Omni Scribe strip chart recorder. Perkin Elmer Sigma 10 Data Station
- Thin Layer Chromatography (TLC). Ultra Violet Products, Inc., Chromat Vue Model C-70

REAGENTS:

- Water, acetonitrile, acetone, methanol, and ethanol for HPLC mobile phase and for preparing standards and solutions were HPLC grade. All chemicals used were ACS Reagent grade
- Dichlobenil (2,6-dichlorobenzonitrile) 97 percent Aldrich Chemical Co. Fluridone, (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) 97 percent Lilly Lot No. X-36950
- 2,4-D (2,4-dichlorophenoxy acetic acid) PolyScience Corp.

Determination of Chromatographic Conditions for Fluridone Standards

Published methods for the determination of fluridone in aqueous samples were evaluated.[1,2,3] The chromatographic conditions described by West and Day[2] using a mobile phase of methanol and water (65:35), 1-ml samples, and a fixed wavelength detector (254 nm) were unsuitable for the determination of fluridone in hard water samples with the equipment available. Excessive pressure developed in the system when methanol eluent was used. This problem was attributed to precipitation of salts, particularly $CaSO_4$ and $MgSO_4$, by the methanol. Both natural pond water and reconstituted water have a relatively high concentration of sulfate ions, and hardness was in the range of 160-180 mg/ℓ $CaCO_3$. It was determined that an acetonitrile:acetic acid eluent afforded separation with reduced adverse effects.

* This appendix was written by Ms. A. O. Jones, USDA, Fort Lauderdale, Fla.

Optimum chromatographic conditions for the analysis of fluridone standards using 2,4-D as internal standards are as follows:

- Mobile phase: Acetonitrile: 1 percent acetic acid in hydro water (1:1)
- Flow rate: 2.1 ml/min
- Detection: UV 238 nm 0.04 AUFS

A series of standards in natural pond water was used to determine the detectable limit and linearity from 0.05 to 10.0 mg/ℓ. Fluridone in natural water can be reliably measured from 2.0 to 480 ng (40-$\mu\ell$ injections of 0.05 to 12 mg/ℓ). Linearity was observed throughout the whole range.

Preparation of Water Samples for Fluridone Analysis

Natural water samples were observed to have a significant amount of particulate matter which collected on the columns, resulting in interference in the analysis and frequent delays to allow column cleanup. When the natural water samples fortified with fluridone standard were filtered through a Metricel® GA-6 (0.45 μ) system, ca. 75 percent fluridone was recovered. Fluridone in the low rates of treatment (< 0.1 mg/ℓ) used in the evaluation program could not be reliably measured. A concentration and cleanup procedure was developed, omitting filtration, using C-18 SEP PAK® cartridges. Accurate quantitation of 0.005 mg/ℓ fluridone was made for 50-ml samples prepared by the following method:

- Acidification with 5 percent H_2SO_4 to pH 3.
- Concentration of fluridone on SEP PAK® C_{18} (reverse phase) cartridges.
- Elution with 2 ml acetonitrile.
- Quantitation of 30-$\mu\ell$ samples by HPLC.

Samples from the flowing water study were prepared by this method.

Verification of Fluridone Content in Monolithic Fiber Formulation

The total amount of fluridone available in the monolithic fiber formulation was verified prior to determining release rates. Fluridone was recovered from the fibers by extraction with ethyl acetate or methanol and by dissolution of the fiber in acetone. The fluridone recovered was measured by HPLC and found to be 100 ± 1 percent of the theoretical amount available.

Verification of the fluridone recovered was accomplished by the following methods:

- Thin layer chromatography (TLC)
- Method of additions
- Absorbance ratios

Fluridone was separated and identified using TLC plastic plates precoated with silica gel 60 F_{254} (E. Merck). Methanol and acetone extracts of the fiber formulation were co-chromatographed with a fluridone standard using a solvent system of toluene, acetonitrile, and acetic acid (65:35:1 v/v). The separated substances were visualized by UV light at 254 nm.

Verification by method of additions was accomplished by dilution of three 10-mg/l sample aliquots as follows:

- With water (1:1)
- With 10 mg/l fluridone standard (1:1)
- With 20 mg/l fluridone standard (1:1)

Quantitation with HPLC was made by measuring peak heights and by integration of areas.

Verification by absorbance ratios was made by HPLC and a Perkin Elmer Auto Control LC 75.[4] Absorbances were measured on the leading edge, the crest, and the trailing edge of the peak at 238, 254, and 285 nm. Ratios of absorbances for fluridone standards at 238 and 285 nm were used for comparison. It was determined that the absorbance ratio of the compound extracted from the fiber corresponded to that of the fluridone standard and was a single substance.

Accountability of fluridone in the monolithic fibers used to determine release rates in static water was made by quantitating fluridone in solution and in the methanol extract of the fibers. Approximately 95 percent of the theoretical available fluridone was recovered from both natural pond water and reconstituted water treatments.

Determination of Chromatographic Conditions for the Analysis of Dichlobenil - HPLC

Chromatographic conditions described by Connick and Simoneaux[5] for the determination of dichlobenil were evaluated and modified using standards of 0.1 to 10 mg/l in deionized and natural pond water. Optimum conditions for separation and quantitation of dichlobenil using 2,4-D as internal standard were found to be the same as those used for 2,4-D and fluridone:

- Mobile phase: acetonitrile: 1 percent acetic acid in hydro water.
- Flow rates: 2.1 ml/min
- Detection: UV 238 nm 0.04 AUFS

The detection limit for neat samples of dichlobenil is 5 ng (50 μl of 0.1 mg/l). The lower detection limit for samples concentrated by extraction into hexane is undetermined but is < 0.005 mg/l.

Determination of Dichlobenil Available in Various Controlled Release Formulations

The total amount of dichlobenil available in the formulations Casoron GSR, D1, and D2 was determined by extraction with methanol. The mixture was sonicated, allowed to stand 72 hr, and sonicated again prior to sampling. Quantitation on diluted samples was made by HPLC. The internal standard used was 10 mg/l 2,4-D. The amount of dichlobenil recovered after 72 hr was ca. 100, 70, and 30 percent, respectively, of the theoretical amount. When the methanol extracts were sampled after 39 days, dichlobenil recovered was 100, 88, and 66

percent, respectively. Verification of dichlobenil was made by the method of additions described above.

Determination of 2,4-D in Water Samples

The methods used for water sample preparation and 2,4-D quantitation are described in an earlier report.[6] Chromatographic conditions were modified for use with the high speed column and are as follows:

- Mobile phase: acetonitrile: 1 percent acetic acid in hydro water (50:50)
- Flow rate: 2.1 ml/min
- Detection: UV 285 nm 0.04 AUFS

Determination of 2,4-D in Clay Pellet Poly (GMA) 2,4-D

Available 2,4-D in the clay pellet formulations and in the polymer Poly (GMA) 2,4-D was determined by the following procedures:

a. Extraction of 2,4-D from clay pellet formulations Lot 2 and Lot 3 with ethanol, methanol, acetone, and water.

b. Extraction of 2,4-D from the polymer Lot 2 by sonication with methanol, acetone, and water.

c. Verification of the 2,4-D extracted by methods of additions, TLC, and absorbance ratios.

In *a* above 2,4-D was extracted from clay pellet formulation Poly (GMA) 2,4-D Lot 2 by sonication with anhydrous methanol, ethanol, acetone, and water. The solutions were sampled immediately and analyzed by HPLC for 2,4-D content. About 15 percent (w/w) of the theoretical amount of 2,4-D was recovered by extraction with methanol, ethanol, or acetone, and 2 percent with water. The 2,4-D methyl ester, ca. 10 percent, was recovered in the methanol extract. When the methanol mixture was acidified (pH 2), hydrolysis and esterification were observed to proceed to completion within 48 hr, as indicated by an increase in 2,4-D methyl ester. The amount of 2,4-D from clay pellet formulation Lot 3 recovered by extraction with the four solvents was ca. 2 percent. When the methanol extraction mixture was acidified (pH 2), hydrolysis and esterification were observed to proceed more slowly and incompletely than with Lot 2. A mixture of four compounds eluted close to 2,4-D when separated by HPLC. Verification of 2,4-D was made by method of additions and absorbence ratios.

In *b* above 2,4-D was extracted from the polymer Poly (GMA) 2,4-D Lot 2 by sonication with acetone and anhydrous methanol. There was no significant difference in the amount recovered, ca. 2 percent, from the polymer by either solvent. A significant amount of several compounds, one identified as 2,4-D methyl ester, was measured immediately after mixing the polymer with methanol. The amount of 2,4-D methyl ester was observed to increase with time through 48 hr. The amount of 2,4-D extracted with water was ca. 2 percent of the theoretical amount available. No ester was observed in either acetone or water extractions. When the acetone extraction was dried under nitrogen and brought to volume with methanol (acidified to pH 2 with 5 percent sulfuric acid), hydrolysis

and methylation were observed. The amount of 2,4-D increased to a constant of ca. 10 percent of the theoretical amount available. The amount of methyl ester increased to ca. 88 percent in 48 hr.

Procedures, in *c* above, followed to verify the extracted 2,4-D by method of additions and by absorbance ratios were described earlier. Verification of 2,4-D and 2,4-D methyl ester by thin layer chromatography was performed using 2,4-D and 2,4-D methyl ester standards as references. TLC plastic plates precoated with Silica gel 60 F_{254} (E. Merck) were spotted with ca. 5 mg (50 μl) samples and standards and developed with a mobile phase of petroleum ether: acetone: acetic acid (50:50:1). Visualization was accomplished with UV light at 254 nm.

The accountability of 2,4-D in the clay pellet Poly (GMA) 2,4-D Lot 2 treatments to static water was made by residue analysis of 2,4-D in:

- The unfiltered aqueous phase
- The filtered aqueous phase
- An ethanol wash through the filter
- An ethanol extraction of filter and sediment
- An acetone extraction of filter and sediment, followed by drying and hydrolysis with methanol (pH = 2)

Approximately 100 percent of 2,4-D was recovered from reconstituted water treatments and ca. 73 percent from pond water treatments.

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